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The Glasgow Naturalist

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Front cover Mouth area of a common sunstar (*Crossaster papposus*), FSC Millport, Isle of Cumbrae, Scotland, 9th September 2021. (Photo: Eleni Christoforou)

Back cover Common sedge (*Carex nigra*), Lennox Park, Milngavie, East Dunbartonshire, Scotland, 19th May 2021. (Photo: Richard Sutcliffe)

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Edited by: Iain C. Wilkie & Christopher J. McInerny

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The Glasgow Naturalist (2022) Volume 27, Part 4, 1-2

EDITORIAL

Establishing the facts

I.C. Wilkie

Institute of Biodiversity, Animal Health and Comparative Medicine, University of Glasgow, Glasgow G12 8QQ

E-mail: iain.wilkie@glasgow.ac.uk

A notable strength of *The Glasgow Naturalist* is the taxonomic breadth of the submissions received. The articles in this issue, for example, deal with organisms ranging from the familiar – great tits and cockroaches – to groups most of us will never encounter (and may not have heard of) – spiny-headed worms from hedgehog faeces and barnacles that live on the shells of sea turtles. The article on great tits (Maciver, 2022) includes the first report of pellet regurgitation in great tit nestlings, a reminder that there may be new things to discover about the natural history of even the commonest and most intensely studies species. As observed by Staab *et al.* (2014), it is highly likely "that there are very many functionally important life-history traits yet unknown across the tree of life, both in already known species and in species awaiting discovery." In a time when ecosystems are under various threats, the need for basic observational natural history has never been more important.

This issue includes the third and final part of the supplement *On the Wildside Revisited: 200 Years of Wildlife in the Glasgow Botanic Gardens* (hereafter "OtWR"). The whole series comprises 18 articles occupying around 68 pages, which contrasts with the seven articles and 21 pages of the original *On the Wildside* supplement ("OtW") (Hancock, 1998, 1999). Therefore, although not dealing with some of the groups covered in OtW – notably vascular plants and several animal phyla found in freshwater – OtWR provides a more detailed account of the groups that are included. It also incorporates two major groups – bryophytes and lichens - that were omitted from OtW.

According to the most recent data (January 2022; https://www.gnhs.org.uk/biodiversity/GBG_splist.pdf), 1,510 species, subspecies and varieties have been recorded in Glasgow Botanic Gardens. Of these, 580 (38%) are insects, which are by far the most speciose group, second place being occupied by flowering plants with around 400 species, subspecies and varieties. Glasgow Botanic Gardens reflects in miniature the world dominance of insects, which are estimated to account for over 50% of all described species (Tihelka *et al.*, 2021). This statistic partly fuels current fears over an impending "insectageddon" widely promoted in both the popular press (e.g. Carrington, 2019; Goulson, 2021) and scientific literature (Hallmann *et al.*, 2017; Cardoso *et al.*, 2020). Cardoso *et al.* (2020) suggest that half a million insect species face extinction in the coming decades. However, the picture is far from clear-cut. Data from the Rothamsted Insect Survey, collected over the last 30 years, indicate that "severe declines [in insect biomass] are not supported by the world's longest-running insect population database" (Macgregor *et al.*, 2019, 2021). Other independent evidence also contradicts the prevailing concern: the U.K. Bat Index, a measure of the relative abundance of 11 of the U.K.'s 17 bat species, increased by 47% between 1999 and 2019 (JNCC, 2021), which is hard to reconcile with a collapse in insect populations, at least within a U.K. context.

Within the Scottish context, there has been in the last year widespread dissemination of a general "apocalypse now" message. For example, in a press release the CEO of NatureScot (formerly Scottish Natural Heritage) was quoted as saying "Scotland has already lost nearly 25% of its wildlife" (NatureScot, 2021a). In subsequent promotional material, NatureScot asserted "We've already lost nearly 25% of our wildlife in Scotland, with… 11% of our species facing extinction" (NatureScot, 2021b). More recently, the latter statistic was endorsed by the Scottish Wildlife Trust in a donation request mailed out in spring 2022: "1 in 9 species in Scotland faces extinction." These figures imply that Scotland's wildlife is undergoing a catastrophic decline: nearly a quarter of it has disappeared. What are the facts?

The source of these figures is the latest *State of Nature Scotland* report (Walton *et al.*, 2019) in which it is stated that since 1994 there has been an average reduction of 24% in the relative abundance of 352 monitored species. As there are around 60,000 organisms (excluding microbes) in and around Scotland (NatureScot, 2021c), this finding is based on information from 0.6% of Scottish species. Furthermore, the *State of Nature* authors do not claim that these species are representative of the Scottish biota: they are restricted to four iconic groups – moths, butterflies, birds and mammals; no plants, fungi or lichens are included; no marine species;

no beetles or flies, the most species-rich insect orders in Scotland. It is a misrepresentation of the facts to equate an average drop of 24% in the abundance of an unrepresentative 0.6% of Scottish species with the loss of nearly 25% of Scottish wildlife.

On a comparable note, the claim that 11% (1 in 9) of our species are facing extinction is derived from the assessment of 6,413 species using Regional Red List criteria: 11% of these have been formally classified as threatened, i.e. all that can be deduced from the *State of Nature* data is that 642 species – 1.1% of all Scottish species, not 11% - are at risk of extinction. Since only 10% of Scottish species have been assessed, we do not know what proportion of the Scottish biota is threatened; it could be much more than 11% or it could be much less.

Is this nit-picking? Does it matter if NatureScot and the Scottish Wildlife Trust "extrapolate beyond the data" in their mission to heighten awareness of the biodiversity crisis? The truth surely does matter. What is known with certainty, e.g. that over 640 species are at risk, is alarming enough without having to be exaggerated. The limitations of current knowledge that are exposed in the *State of Nature* report should be an incentive to all naturalists to get out into the field and find out what is really going on. This further emphasises the importance of observational natural history. To quote Staab *et al.* (2014) again: "Accurate and holistic data on species, traits, and communities will be vitally important to predict response of species and ecosystems to global change…". We all have a duty to establish the facts.

ACKNOWLEDGEMENTS
The comments above on "insectageddon" owe much to the clear and considered explication of this issue in McIntosh (2020). I am very grateful to Chris McInerny, Ruth Maclachlan and Richard Weddle for their assistance in the editing, assembly and website presentation of the journal, and to the external experts whose critical evaluation of submitted manuscripts is crucial in maintaining the journal's scientific standards. The external reviewers for this issue were (in alphabetical order): K. Alexander, M. Culshaw, J. Dodd, E.G. Hancock, N. Hand, S.A. Hinsley, A. Lavery, I. MacDonald, C. Poirier, G.P. Rotheroe, N. Simpson, M. Wayland, R.B. Weddle, N.A. Welden, A. Whiffin and J.D. Zardus.

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FULL PAPERS

False blister beetles of the genus *Oedemera* in Scotland

B. Philp

7 Glebe Crescent, Ochiltree KA18 2QP

E-mail: brucephilp47@gmail.com

ABSTRACT

The status and distribution of the Scottish false blister beetles (Oedemeridae) are summarised with particular reference to the genus *Oedemera.* Within this genus only three species have been reliably recorded in Scotland. Of the two widespread species virtually all the records are post-1990. One species - *O. virescens* - appears to be very common in the south of Scotland whereas the other species - *O. lurida* - is recorded mainly north of the central belt. While identification problems may partly account for these differences, they do not appear to provide a complete explanation with other unknown factors influencing their distribution.

INTRODUCTION

The Oedemeridae is a relatively small family of soft-bodied, elongate beetles that could be mistaken for soldier beetles (Cantharidae) or longhorn beetles (Cerambycidae). In total there are ten species in Britain, although only six of these occur in Scotland including *Chrysanthia geniculata*, which is restricted to a single site on Deeside (Duff, 2020) and *Nacerdes melanura,* an introduced species that is found in waterlogged wood, usually around the coast. There is a single record of *N. melanura* in Scotland according to the NBN Atlas (National Biodiversity Network, 2021a), although Richard Lyszkowski (pers. comm.) regards it as not uncommon on the east coast, and the Glasgow Museums Biological Records Centre has two records from Glasgow (R.B. Weddle, pers. comm.).

The remaining four species belong to the genus *Oedemera.* Three of these are superficially similar leading to difficulties with identification and consequently this has led to confusion over their distribution. The identification of the four species is well described in Duff (2020) and will not be repeated here; instead what is known of their current distribution in Scotland will be reviewed.

THE *OEDEMERA* SPECIES

As adults of the four species feed on flowers, they can be quite conspicuous and are often numerous. More than one species can be present at the same site and since three are green in colouration it can be challenging to separate them.

Oedemera femoralis

The largest species is *O. femoralis*, which is brown rather than green and measures 13-20 mm in length (this and subsequent dimensions from Duff, 2020). However, it has a distinctive elongate shape with slim elytra which taper towards the rear and characterise the genus (Fig. 1). Unusually for a British beetle it is mainly nocturnal with an apparent preference for ivy (*Hedera helix*) (Duff, 2020). A recent summary of the status of several families of British beetles classifies *O. femoralis* as Nationally Scarce, meaning that it has been recorded from just 16-100 hectads (10x10 km squares) in Britain since 1990 (Lane *et al.*, 2019).

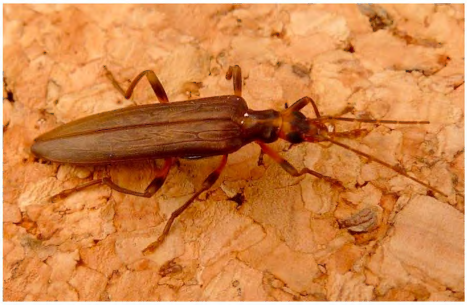

Fig. 1. *Oedemera femoralis*. (Photo: ©gailhampshire)

In Scotland its status is uncertain. The review of the family by Alexander *et al.* (2014) includes it as Scottish while the NBN Atlas has no Scottish records. However, Crowson (1964) found larvae in thick ivy stems at Portencross in Ayrshire, while it has also been reported from Abbey Craig near Stirling (Waterston, 1935; Cathrine *et al.*, 2020; Richard Lyszkowski, pers. comm.), in these cases associated once again with ivy. A further record was reported in 2012, although the exact location is not known (Sullivan, 2012).

The scattered records noted above show no obvious pattern and it seems possible that it may be more widely distributed although probably scarce. There is certainly no shortage of ivy and so perhaps its nocturnal habits have kept it from wider notice. Beating ivy at night may well produce new records.

Oedemera nobilis

Known as the swollen-thighed beetle, this is a common species in England and Wales from the Midlands southwards, with scattered records in northern England (National Biodiversity Network, 2021b). The grossly swollen hind femora make the male unmistakable, but the female is more similar to the following two species, although generally it is a brighter green. *O. nobilis* of both sexes are distinctive in having relatively narrow elytra that do not meet in the middle towards the rear (Fig. 2). While their length (6-11 mm) overlaps with that of *O. virescens* and *O. lurida* (Vásquez, 2002; Duff, 2020), their brighter green colour should make even the females distinctive.

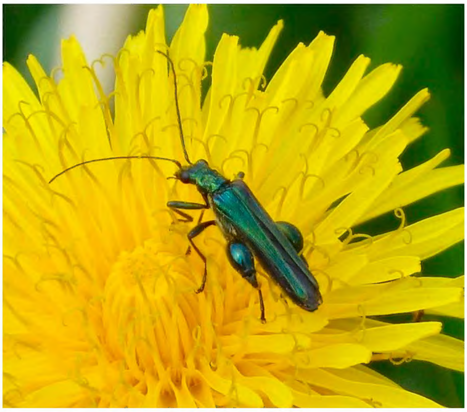

Fig. 2. *Oedemera nobilis* (male). (Photo: ©gailhampshire)

A review of the status of the Oedemeridae (Alexander *et al.*, 2014) gives no records for Scotland, but two are noted in the NBN Atlas. One of these is an error, as acknowledged by the recorder and the other is unverified. There are also four records in the Biological Records Centre's iRecord but, from the accompanying photographs, these are, with one exception, *Oedemera virescens* or *lurida*. The exception is a male but, while the grid reference suggests a site near Leadhills, Lanarkshire, the accompanying written description states that it is in Nottinghamshire. Because of the similarity between the three species, records for *O. nobilis* should be accepted only where a photograph exists or where the recorder is experienced with the species. The generally southern distribution suggests that this species is unlikely to be found in Scotland.

Oedemera virescens

The features that characterise this species can be quite subtle. It has a length of 6.5-11 mm and is frequently described as being a dull, sage-green in colour. The hind femora of males are swollen (Fig. 3), although not nearly as much as those of *O. nobilis.* The females have thin hind femora, as in *O. lurida,* and can be difficult to distinguish from that species. They can, however, be separated from *O. lurida* by the shape of the last ventral abdominal segment. This can be difficult to see in these soft-bodied insects and needs to be examined carefully.

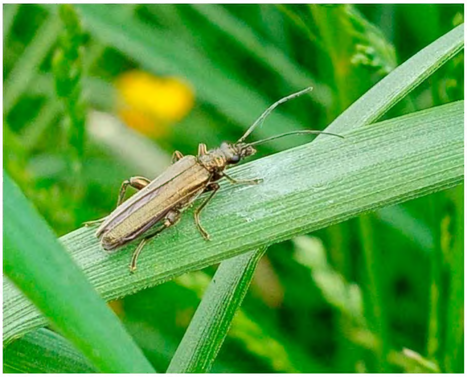

Fig. 3. *Oedemera virescens.* (Photo: B. Philp)

This is the least common species of the genus in Britain with Lane *et al.* (2019) giving it Nationally Rare status signifying that it has been recorded in fewer than 15 hectads in the U.K. since 1990. Indeed, in a previous review of the status of British Coleoptera, Hyman & Parsons (1992) regarded it as a Vulnerable Red Data Book species, as they stated that it had been recorded in only three hectads between 1970 and 1990, all of them in north-east Yorkshire. The first Scottish record was from the Forest of Ae in Dumfriesshire in 1992/93 (Morris, 1997) followed by a few scattered records until an upsurge from around 2010. After this, and partly as result of targeted appeals for records (Philp, 2014; and unpublished), many more records were received. With now well in excess of 200 records from 72 hectads, all in the south of Scotland (Fig. 4), it would appear that the species can no longer be regarded as Nationally Rare.

The apparent significant increase in the range of this species cannot be attributed solely to the targeted recording mentioned above. Feeding in large numbers on its favourite buttercup (*Ranunculus* spp.) flowers between May and July, it is a very conspicuous insect and it seems unlikely that it was overlooked by earlier coleopterists. It would appear that there has been an expansion in the species' range and, although there might be a temptation to link this to the effects of climate change, there is no direct evidence to support this idea.

Oedemera lurida

With a length of 5-8 mm, this is the smallest of the *Oedemera* species, although there is considerable overlap (Vásquez, 2002; Duff, 2020). It is much the same sage green colour as *O. virescens* with both sexes having thin hind femora (Fig. 5). Once again, the shape of last ventral abdominal segment of the females is distinctive but difficult to confirm without magnification.

Surprisingly, Alexander *et al.* (2014) do not include Scotland in this species' range, although it was recorded from the Pitlochry area in Perthshire in 1884 (Beaumont, 1884). Beaumont gives the specific name as *Oedemera livida*, although Fergusson (1914) in listing recent

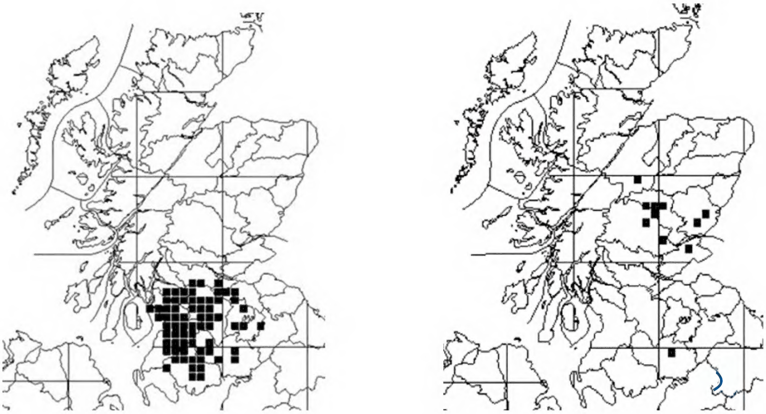

Fig. 4. Scottish records up to 2021 of *Oedemera virescens* (left) and *O. lurida* (right). Compiled by the author using MapMate.

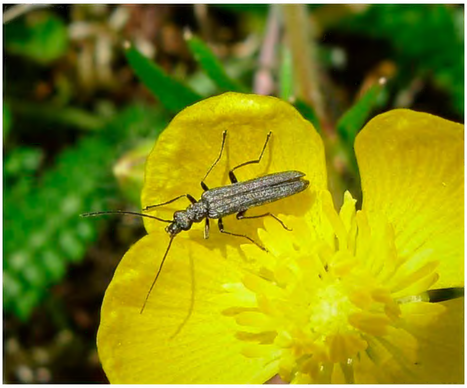

Fig. 5. *Oedemera lurida.* (Photo: ©gailhampshire)

additions to Scotland's beetle fauna called it *O. lurida*. The next records are from 1991 (Magnus Sinclair, pers. comm.) with another two up to 2000 (National Biodiversity Network, 2021c), all of them within mid-Perthshire. Since then, there have been several more records with the range being extended to Inverness-shire, Angus, Fife and, with one recent record, Dumfriesshire (Steve Lane, pers. comm.) (Fig. 4). The very small number of confirmed records in central and southern Scotland is surprising as the species is relatively frequent in the north of England, and it seems likely that it must be more widespread than these records suggest. The similarity of both sexes of *O. lurida* to female *O. virescens* means that the verification of records is difficult, whereas *O. virescens* males can be easily confirmed from photos.

DISCUSSION

Of the five species of Oedemeridae that have been reliably recorded in Scotland only two - *O. lurida* and *O. virescens* - appear to be widespread. Surprisingly, there seems to be only a single record of either species until the 1990s. For species that are relatively large and conspicuous and which can readily be found in feeding in numbers on flowers such as buttercups this is surprising. It is unlikely that prolific recorders such as Sharp, Fergusson and Crowson could have overlooked them. It would therefore appear that there has been an increase in numbers and/or a significant range expansion. Possible explanations for this include land use changes, and climate-induced habitat factors but these have not been investigated for these species.

Because there are many records of *Oedemera* that cannot be attributed to a species ranging from the Scottish Borders to the Isle of Skye, the true extent of the ranges of the two species cannot be defined precisely. However, because *O. virescens* males are relatively easy to identify in the field, the Scottish distribution shown in Fig. 4 may be reasonably accurate. The situation regarding *O. lurida* is more complicated and more recording in the south of Scotland by experienced coleopterists may show it to be more widespread, although personal experience suggests that it is likely to be the less frequent species.

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The production of regurgitation pellets in the great tit (*Parus major*)

S.K. Maciver

Centre for Discovery Brain Science, Biomedical Sciences, Edinburgh Medical School, University of Edinburgh
EH16 4TJ

E-mail: smaciver@ed.ac.uk

ABSTRACT

The nesting behaviour of the great tit (*Parus major*) from nest preparation to fledging was followed continuously by video-recording in two identical nest-boxes over two seasons during 2020 and 2021 in the same large rural garden. Unexpectedly, the production of a series of regurgitation pellets (RPs) by the nestlings was recorded during the 2020 season. No pellet regurgitation was recorded during the 2021 season. Recordings were also made of adult great tits producing small RPs as they roosted. I suggest that this unprecedented RP production by nestlings resulted from the consumption of suboptimal food items due to the poor breeding season of 2020.

INTRODUCTION

The capacity for flight allows birds to travel rapidly to explore food resources and to escape ground-based predators, but this ability comes at a cost. Weight must be minimised and so the digestive track is as short as possible. This compromises complete digestion and so many birds remove indigestible material regularly by expelling it from the upper gut in the form of a regurgitation pellet (RP) (Leprince *et al*., 1979). Many birds of prey produce RPs as they tend to swallow prey whole and their RPs consist almost entirely of fur, feather and bone. Many passerines are reported to produce RPs (Tucker, 1944; Davies, 1977a,b; Taylor & O'Halloran, 1997; Jehl, 2017), and RP production has been also reported in nestlings (da Paz Pereira & Melo, 2012). RPs are often produced when the bird preys on large quantities of insects, particularly when these insects have heavy chitinous exoskeletons. Chitin, a linear β1,4-linked polymer of N-acetyl-D-glucosamine, is digested by a range of chitinases and its complete digestion involves several different enzymes (Suginta *et al*., 2010). The chitin in the cuticle of insects is present as a matrix of proteins, lipids and, in some species, significant amounts of calcium (Kramer *et al*., 1995) and these affect the digestibility of the cuticle, meaning that digestion is seldom complete and chitin fragments are expelled as faecal pellets or regurgitation pellets. This observation has been used by many workers to investigate the diet of birds (Taylor & O'Halloran, 1997; Davies, 1977a,b).

The reasons why birds produce RPs differ substantially between bird groups. In the case of birds of prey, regurgitation is necessary to rid the bird of indigestible material such as fur and bone from their prey. In other cases, the reason is less clear. Members of the grebe family, for example, are known to eat their own feathers and produce feather-containing RPs (Simmons, 1956; Kop, 1972; Jehl, 2017). Many explanations for this well-documented habit have been offered but it seems most likely that the feather mass allows more complete digestion of their often poorly digestible food by delaying gut transit (Jehl, 2017).

Illness or intoxication is another cause of regurgitation. For example, the spotted fritillary butterfly *Melitea didyma* sequesters iridoid glycoside toxins from its plant food, which has been found to cause vomiting/regurgitation in a great tit (Tesařová *et al*., 2013). Plants such as mistletoe *Viscum album* (Mathiasen *et al*., 2008) and guelder rose *Viburnum opulus* (Hernández, 2009) rely on birds to spread their seeds through regurgitation and faecal discharge. These plants stimulate regurgitation while providing the birds with some nutrition.

The ability of birds to regurgitate is suggested to be a function of the musculature of the gizzard (Hart & Thompson, 1995) and this has been crudely quantified by the administration of emetics (Prŷs-Jones *et al.,* 1973). The spot-winged tit *Periparus melanolophus*, a relative of the great tit, was discovered to be able to regurgitate by this criterion (Prŷs-Jones *et al.,* 1973).

Here I report that great tits produce RPs at the roost, and I report for the first time that nestling great tits produce RPs. I hypothesise that, in the case of the nestlings, RP production results from the ingestion of suboptimal food items during a poor breeding season.

METHODS

A small wi-fi connected video camera (NCIP2WF, Green-feathers.co.uk, Bristol, England) was installed in a new 21 mm thick pinewood nest-box (31×13×13 cm internal dimensions, with an entrance hole 32 mm in diameter) in a large garden in Penicuik, Midlothian, Scotland (Lat. 55.8280, Long. -3.2449, elevation 224 m). The garden faces open agricultural land and deciduous woodland. This nest-box (hereafter referred to as the spruce nest-box) was firmly attached to an 8 m high Norway spruce tree (*Picea abies*), 2.5 m off the ground and 9 m from buildings, with the entrance hole facing northward to avoid direct sunlight, and the prevailing winds. A white-light LED lamp with a daylight detector illuminated the interior of the nest-box until the hours of darkness, when the white LED lamp was switched off and the camera switched automatically to infrared mode, to continually capture video. Some videos were recorded using an infrared camera (CMOSNC720M) in a similar setup, but without the LED lamp. Video was displayed and recorded on a Windows 10 PC using OBS Studio 25.0.8 video recording and streaming software (obsproject.com). A second identical nest-box with a video camera was placed 20 m away from the first in the same garden. This nest-box was attached to a holly tree (*Ilex aquifolium*) 2 m off the ground. In the 2021 season, this nest-box (hereafter referred to as the holly nest-box) was occupied by a pair of great tits which laid six eggs and successfully fledged all six chicks. Videos were annotated and edited using Moviemaker (Microsoft). Times and dates were automatically displayed on all video recordings. Still photographs outside the nest were taken with a Canon EOS 760D SLR camera with a Sigma DG 150-500 mm telephoto lens.

RPs were taken from the nesting material after the 2020 season nestlings had fledged. One RP which was recorded being produced by a nestling was retrieved from the nest periphery and was the known product of a nestling and not either parent. The composition of this RP was investigated by staining with three classic histochemical stains: Oil Red O (Sigma Aldrich, Dorset), which is specific for oils/droplets; Congo Red (benzidinediazo-bis-1-naphthylamine-4-sulfonic acid sodium salt) (Sigma-Aldrich), which stains chitin (the principal component of insect exoskeletons) and cellulose (plant cell walls); and Coomassie Blue R250 (Sigma Aldrich), which is specific for proteins. Congo Red and Coomassie Blue dyes were dissolved in a 50 mM phosphate buffer at pH 7.5, and Oil Red O was dissolved in isopropanol. The pH of other RPs was investigated by placing small RP fragments, moistened with deionised water, on litmus paper. The RP material available was very small and so a more thorough qualitative investigation was not possible. The pellets were investigated microscopically using a Leica inverted microscope with Hoffman modulation contrast optics. Images were recorded using a Canon EOS 1100D camera attached to the microscope.

RESULTS

Having built the nest alone, as is usual for the great tit (Perrins, 1979), the female roosted overnight on 11th May 2020 and by 19:37 BST on 12th May it was apparent that three eggs had been laid in the spruce nest-box, but they were obscured first by the female and then by the nest material. A further single egg was laid at approximately 20:00 on 14th May. After a 13-day incubation period (starting from when the last egg was laid), on 27th May, all four eggs hatched, the first at 10:55, the second at 11:50, the third at 14:53 and the fourth at 16:30. The standard time of incubation for great tits is 13-16 days (Perrins, 1979; Gosler, 1993). Both parents began feeding the hatchlings as soon as they were hatched (Fig.1 a,b). Nestlings usually fledge after 18-21 days (Gosler, 1993), but both parents continued to feed nestlings in the nest on day 22, when the surviving pair fledged. A clutch of only four eggs is small compared with the average for great tits of 8.1 for this location (pers. obs.) and this clutch had a longer than average fledge time as is typical of suboptimal habitats such as gardens (MacKenzie, 2010). A total of 2,132 visits by both parents was recorded during the entire nestling period (Fig. 1a). Very few caterpillars were brought to the nestlings until day 13, as the temperatures were below average. The daily feeding visits built up over the first few days with the male effort being most important in the earlier days but gradually reduced (Fig. 1b).

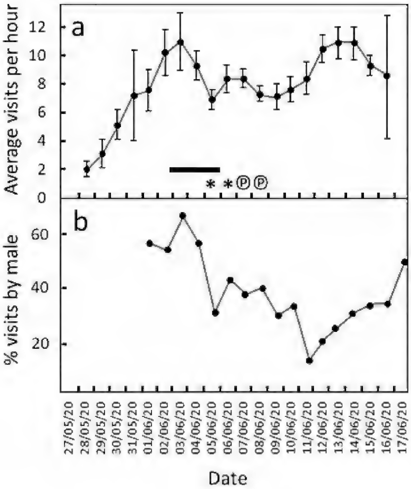

Fig. 1. Spruce nest-box: feeding rate and contribution of male to feeding. (a) Feeding rate. This reached a peak by 3rd June 2020 but then a three-day run of bad weather (black bar) reduced the rate, after which two nestlings died (*). New plant material brought into the nest is indicated by Ⓟ. The rate then slowly increased until 14th June, after which the rate declined until fledging. Error bars indicate standard error. (b) Contribution of male to feeding. This exceeded that of the female until 5th June 2020. The male's relative contribution steadily declined, rising again on the day before fledging but only because the female's effort decreased.

Several episodes of pellet regurgitation were recorded, the first occurring when the nestlings were eight days old (Fig. 2a) and while all four were still alive in the nest. These regurgitation events (Fig. 3a-d; video 1 at https://youtu.be/LKZ0OMNLbF4) occurred day and night, although some events occurred unseen under the roosting female at night, the RPs being visible the following dawn. The RPs all had the same distinct appearance, varied in size from 1-5 mm, and often had an angular shape. These events were not obviously correlated with other small-scale events, such as being harassed by a fellow nestling or being jostled by the female while nest cleaning. The RPs were removed from the nest on the next visit by the parent or, if they were expelled at night, as soon as feeding visits resumed the next morning. Parents were also observed removing the

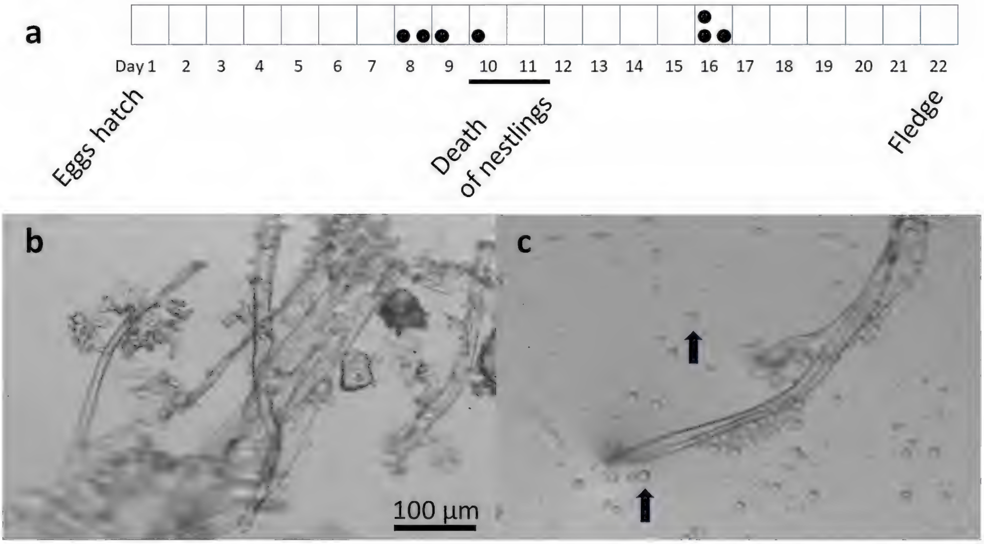

Fig. 2. Spruce nest-box: regurgitation pellet (RP) production and composition in the 2020 season. (a) RP production events (black spots) during the 22 days that the nestlings spent in the nest after hatching, in relation to other significant events. (b,c) Micrographs showing the nature of the RPs. Black arrows indicate putative lipid droplets that are both free and attached to fibrous material. The scalebar applies to both micrographs.

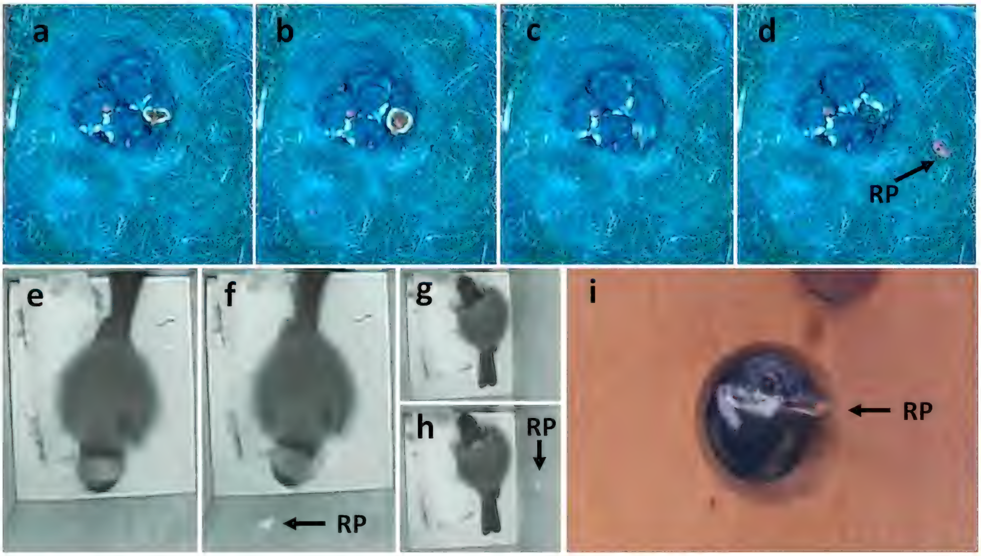

Fig. 3. Stills from videos showing regurgitation pellet (RP) production in nestlings (a-d) and adults (e,f and g,h). (a) The nestling on the right of the image begins to open and close its mouth. (b) A large RP appears in the gullet. (c) The nestling shakes its head vigorously. (d) A large RP is expelled and lands on the rim of the nest (arrow). The RP visible in (d) contains cuticular chitin (two black specks). (e) An adult shakes its head and (f) spits out an RP which adheres to the nest-box wall. (g,h) Similar events as in (e,f). (i) An adult female great tit removes from the nest the RP produced in the event shown in (a-d). Note that the red-orange colour of the RP is very different from the grey-white colour of the faecal sacs that were also removed from the nest-box by the parents.

RPs from the mouths of nestlings (video 2 at https://youtu.be/wCbXDkaCJtk). Two regurgitation events were also recorded in an adult great tit roosting in the spruce nest-box, one at 23:09:33 on 24th August 2020 and the other at 23:54:16 on 2nd Sept 2020 (Fig. 3e-f, g-h; video 3 at https://youtu.be/-ElSoAHK-r4).

A single RP was recovered from the periphery of the nest after fledglings had departed. This particular pellet had been seen to be moved to the peripheral position during the roost by the female and it had been overlooked in subsequent hygiene sweeps by the parent birds. When removed from the nest the pellet was pale orange (having been more distinctly orange on production), and of a chalky composition. The pellet was found to be largely insoluble in water and contained fibrous material and oily globules that were both free and attached to the fibres making up the bulk of the material when viewed with the microscope (Fig. 2b). Small fragments of the RP stained distinctly with Oil Red O, a lipid-specific stain, and Congo Red, which stains both chitin and cellulose. There was some staining with Coomassie Blue, a protein-specific dye. The fibrous material showed no indication of being organised into cells and did not appear to be of plant origin. Litmus paper indicated that the pH of the RP fragments was 5-6.

In the 2021 season nest building commenced on 5th April in the holly nest-box and the first of six eggs was laid on 11th May; all hatched on 29th May; and all six hatchlings fledged on 18th June. The parents were recorded making 4,134 visits to the holly nest-box and there were no RPs produced throughout the entire period. The 2021 female was a different individual from that of 2020, but the male could have been the same individual who raised the 2020 brood.

DISCUSSION

Perhaps most birds can produce RPs, but they only do so under certain circumstances. Many birds are believed to produce RPs when their food has a high content of indigestible material. Whereas there is a single report that great tit adults normally produce RPs (Gibbs, 1957) after eating seed, I now report that great tit nestlings also produce RPs and present video evidence in support of this observation. Nestlings were seen disgorging RPs with some difficulty (video 1, https://youtu.be/LKZ0OMNLbF4). Regurgitation in both the nestlings and the adults was accompanied by vigorous head-shaking movements, apparently in an instinctive attempt to use centrifugal force to dislodge the RPs. While only a very preliminary biochemical investigation of these RPs was possible because of the limited material available, it was found that the great tit RPs were acidic (pH 5-6), in agreement with the findings of Leprince *et al.* (1979) who studied the RPs of raptors. They contained protein, again in agreement with former studies (Leprince *et al.*, 1979), lipid and chitin.

The parents reacted to the production of RPs by helping the nestlings remove them from their mouths. As parents also remove excess food from the mouths of nestlings if the nestlings cannot swallow the mass, this action pattern may explain RP removal when adults are not familiar with RP production by nestlings. Similarly, there is a well-documented instinct to remove objects from the nest in many passerines (Poláček *et al.*, 2013), and so it is also possible that RPs are removed on this non-specific basis alone, without there having to be a specific familiarity with the regurgitation process or its products.

The first series of RP productions coincided with the death of two nestlings. It was not possible to identify which nestling produced the RP and so it is possible that the two events were unrelated. However, it remains a possibility that the nestlings died as they choked on RP pellets or that the RP pellets obstructed their gullets. Although the removal of the dead nestlings was video-recorded, the corpses could not be found after they had been removed from the nest-box by the mother, so the cause of death could not be investigated. Obstruction of the gullet is, however, a genuine threat to great tit nestlings: Cowie & Hinsley (1988) reported that they found dead nestling great tits with a large piece of peanut wedged in their gullets on three occasions.

On two consecutive days after the death of the second nestling the female adult brought fresh plant material into the nest. The first appeared to be a mass of grass, the second moss. The reason for this is unknown but aromatic plants brought into the completed nest of blue tits (*Cyanistes caeruleus*) were found to reduce the bacterial load on the nestlings but not on the parents (Mennerat *et al.*, 2009), and so this may have been an instinctive act to sanitise the nest.

It is perhaps surprising to make a new observation in a bird species that has been so intensively studied, especially regarding such a striking behaviour. The recent availability of small cameras has greatly facilitated this study, but in addition it is possible that the production of RPs in great tit nestlings is uncommon and that it occurs only under specific conditions. Usually great tit parents time their reproduction to coincide with maximal caterpillar production, caterpillars being the favoured food for their nestlings (Barba *et al.*, 1995, Naef-Daenzer *et al.*, 2004). The 2020 breeding season in this study was sub-optimal in south-eastern Scotland, with cold weather delaying the appearance of caterpillars. The parent birds struggled to find enough caterpillars for their small brood of four, and instead were seen feeding the nestlings other insects such as small beetles, hoverflies, moths, green-veined white butterflies (*Pieris napi*) and spiders. These parents made a total of only 2,132 visits to the nest-box, compared with the 4,727 visits made in raising nine nestling great tits observed in a similar study (Betts, 1955), and 4,134 visits made by parents in the 2021 season with six nestlings in the same garden, again reflecting the poor breeding season reported here in 2020. It was only later in the 2020 season, after two chicks had died, that caterpillars dominated the visible food items brought to the nest-box whereas caterpillars were dominant from the beginning of the 2021 season. RP production may have resulted from the large amount of cuticular chitin present in the caterpillar-poor diet, which the chicks were unable to digest, and large pieces of insect exoskeleton were visible in some of the RPs. If this is the case, then RP pellets may also be produced in regions such as northern Finland where it has been shown that great tits do not have access to caterpillars early in the nestling season (Veistola *et al.*, 1995). It is also evident that, in the event of a second brood, the incidence of adult insects in the diet would be greater, as would the risk of dehydration, because caterpillars would be less abundant at this time.

An alternative possibility is that artificial food from surrounding bird tables could have been fed to the nestlings, causing their gullets to be obstructed. If this is the case, then this cannot be described as normal RP production but merely the spitting out of indigestible artificial food. It is possible too that the fatty material found in the RPs may originate from a "bird cake" or suet block from a local bird table. However, the fibrous appearance of the RPs under the microscope, the visible exoskeletal remains in the pellets, together with the observation that they were produced at night, long after feeding, all suggest that the pellets were genuine RPs. Finally, RPs were recorded from two adult birds, 5 h 20 min and 5 h 1 min after they returned to the roost and thus after their last opportunity to feed, again suggesting that these are genuine RPs produced to expel indigestible components of the diet.

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The composition of strand-line dead-shell accumulations on the Isle of Cumbrae, Scotland

P.G. Moore

32 Marine Parade, Millport, Isle of Cumbrae KA28 0EF

E–mail: p.geoff.moore@gmail.com

ABSTRACT

Data are presented on the composition of identifiable molluscan shell debris from the surface of supralittoral strand-line accumulations from three topographically distinct coastal sites and aspects on the Isle of Cumbrae, Scotland sampled in summer and winter. Interpretation of these death assemblages, termed taphocoenoses, is given with reference to the biology and distribution of the same species living on- and off-shore and prevailing physical conditions at each site. Understanding such relationships allows the reconstruction of fossil deposits of dead shells, termed thanatocoenoses. The significance of dead-shell accumulations as carbon sinks has relevance to current modelling of climate change.

INTRODUCTION

“An assemblage of dead shells commonly represents the accumulation of material over a period of time and is likely to be a mixture of many successive populations” (Brenchley & Harper, 1998). Such death assemblages (DAs), also termed taphocoenoses, are defined as “a set of taxonomically identifiable, dead or discarded organic remains present in the surficial mixed layer of a landscape or seafloor” (Kidwell, 2013; "surficial" means "surface" in this context). These remains represent a time-averaged assemblage, the composition of which varies with time according to episodic supply mechanisms and weathering events on a variety of time-scales: modern and geological. Carroll *et al.* (2003) stated that environmental factors and local fluctuations in populations in shell-producing organisms are more likely to be the principal determinants of time-averaging in marine benthic assemblages. Molluscan data tend to predominate such studies due to their calcareous (aragonitic) body covering which resists attrition and dissolution. Seasonal impacts, especially winter storms, will affect the supply of material (modern and, in some cases, reworked fossil material) thrown-up onto beaches and will also affect subsequent particle comminution and mixing of shells depending on the characteristics of the surrounding site, *viz.* aspect, exposure to wave action, the supply of stones, proximity of hard surfaces etc. Such processes have obvious, and well recognised, import for environmental (physical as well as biological) interpretation of fossil assemblages, termed thanatocoenoses.

DAs have considerable environmental significance in Scotland. Ritchie & Mather (1984) reported that over 50 Scottish beaches are composed almost entirely of shelly carbonate sand (see Farrow *et al.* (1978) and Wilson (1979) for offshore data). Some Scottish shell accumulations are, of course, man-made. The enormous back-shore shell middens on Oronsay (Inner Hebrides, Scotland) are the result of centuries of human shellfish exploitation of limpets, periwinkles, whelks, oysters, cockles, scallops and razorshells since Mesolithic times (Mellers, 1981, 1987; Pollard, 1994), collected for food and bait (Allan, 2017). Modern-day commercial exploitation of shellfish species still results in the disposal of "waste" shell material (Morris *et al.*, 2019). As reported in 2017, every year more than seven million tonnes of mollusc shells were discarded by the U.K. seafood industry; the majority ending-up in landfill or dumped at sea (Anon., 2017), sometimes as cultch for oysters (see Lown & Cameron, 2020). Industrial plants may process mollusc or crustacean shells from which all flesh has been removed (not an easy process) when intended for the production of aggregates for a variety of commercial uses: such as in gardens, construction, maintenance, repair of footpaths, draining the land and ornamental purposes (Archer, 2010). "Shell hash" of mussel shells falling to the seabed both from mussel farms in Scotland (generating anoxic sea-bed patches; see Wilding & Nickell, 2013), and from fouled coastal fish-farming cages (Sanchez-Jerez *et al.*, 2019) also affect benthic ecosystems. Humans are still generating taphocoenoses.

Apart from my earlier DA observations on the dogwhelk (*Nucella lapillus*) (Moore, 1985), no recent work seemingly exists on the topic on the Isle of Cumbrae, North Ayrshire, Scotland (though Boyd (1982) comes geographically closest), since Robertson (1877) noted that the fauna of raised beaches was identical with that living in neighbouring seas. Having been aware, over years of casual observation, of the considerable differences that exist between the appearance of strand-line shell accumulations on different beaches on this small island and of the often different appearance of strand-line material in summer and winter at Ballochmartin Bay, I decided to investigate further. Such a study may not be as esoteric as it might seem, since it has been estimated recently that 1,738 million tonnes (MtC) of inorganic carbon is stored as non-living shell material in Scotland (Burrows *et al.*, 2014) and carbon sequestration is of prime environmental concern at present.

METHODS

A haphazard (not statistically randomised) sample of surficial strand-line dead-shell accumulations from each of three high-shore sites on the Isle of Cumbrae (Table 1; Figs. 1-4, 6) was shovelled into plastic tubs and returned to base where they were riddled through a 1.0 cm mesh sieve. The surficial sample depth was *ca.* 3 cm and each sample produced, after sieving, *ca.* one litre of retained material. Retained material was identified to species wherever possible and counted. Most bivalve shells were disarticulated (at the very least). Such disarticulated valves were counted whenever the hinge line was present. The dry weight (to nearest gram) of each taxonomic category, including broken fragments that could be attributable to species, was recorded wherever possible. Molluscs were identified variously with reference to Tebble (1966), Hayward & Ryland (1990), Oliver *et al.* (2016) and Wigham & Graham (2017). Local habitat information regarding molluscs can be found in Quayle (1952), Clark & Milne (1955) and Allen (1962). All material examined was eventually returned to the site of origin, respecting conservation ideals (Ballochmartin Bay, for instance, is a Site of Special Scientific Interest (SSSI)).

Site	Grid Ref.	Dates sampled	Characteristics
Ballochmartin Bay	NS181571	15/06/2020 07/02/2021	Very sheltered embayment, facing due East (90°), with *ca.* 2.5 km wave fetch; shallow sloping sandy littoral with stable boulders.
South of Fintray Bay	NS155565	16/06/2020 07/02/2021	Steeply shelving, stepped, coarse sand pocket beach, with stones and solid rock in midshore, nearly West facing (256°), between rock ledges, with *ca.* 5.5 km non-deflected wave fetch (*ca.* 18.5 km deflected from SW).
Stinking Bay	NS171590	16 /06/2020 07/02/2021	East corner of small coarse-sand beach, North-west facing (290°) with *ca.* 7.5 km wave fetch, a sediment trap with stones and boulders midshore, adjacent to rocky platforms.

Table 1. Sampling site characteristics on the Isle of Cumbrae, Scotland.

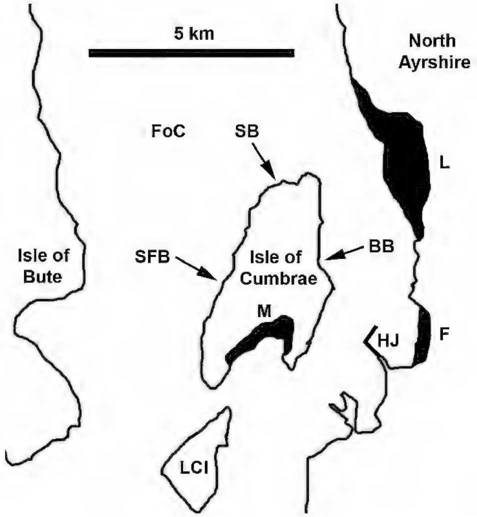

Fig. 1. Map showing the sites mentioned on Isle of Cumbrae, North Ayrshire, Scotland and surrounding locations. BB, Ballochmartin Bay; F, Fairlie; FoC, Firth of Clyde; HJ, Hunterston jetty; L, Largs; LCI, Little Cumbrae Island; M, Millport.

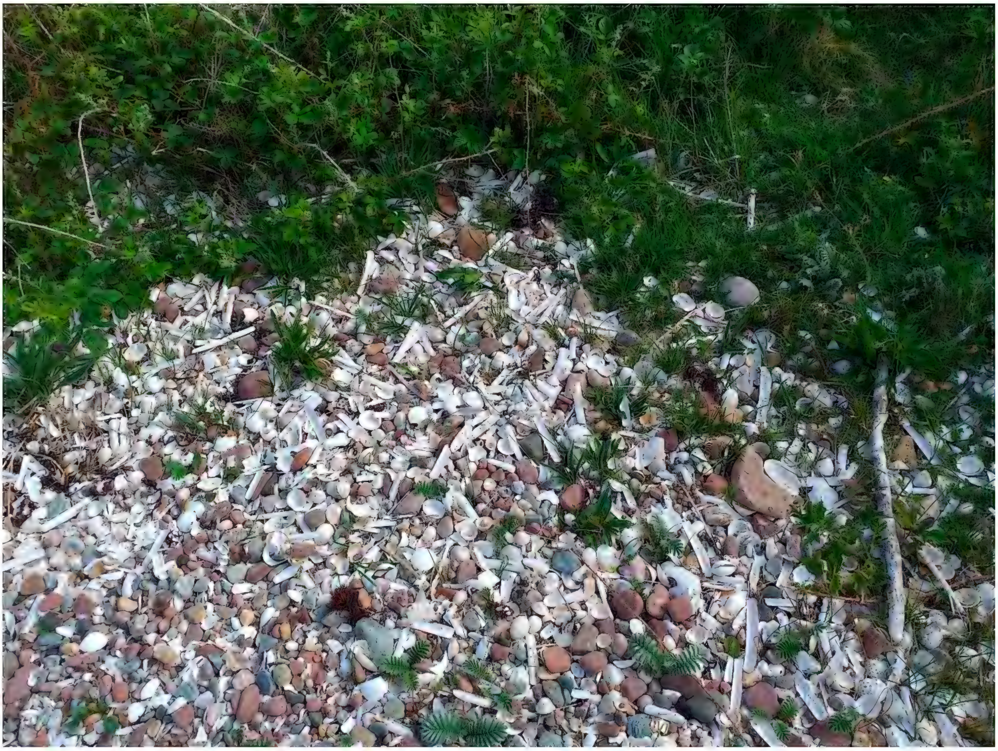

Fig. 2. The appearance of the strand-line at Ballochmartin Bay, Isle of Cumbrae, 16th June 2020. (Photo: P.G. Moore)

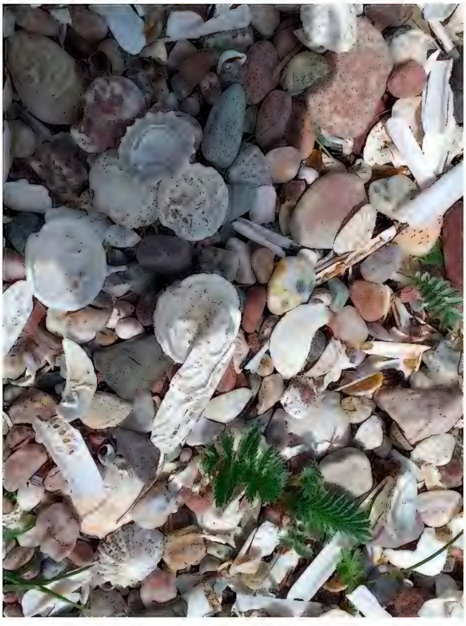

Fig. 3. The appearance of the strand-line south of Fintray Bay, Isle of Cumbrae, 18th June 2020. (Photo: P.G. Moore)

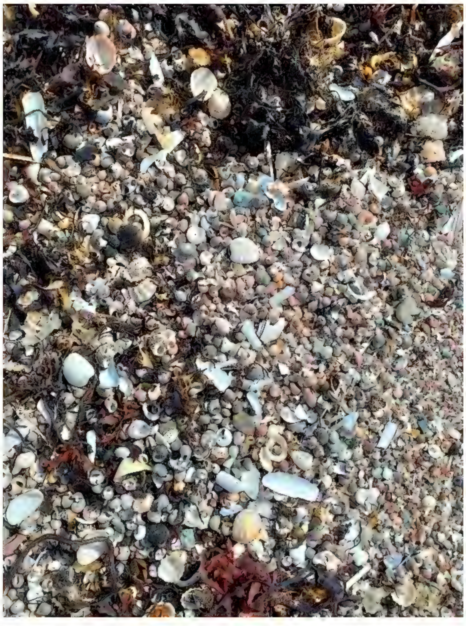

Fig. 4. The appearance of the strand-line at Stinking Bay, Isle of Cumbrae, 19th June 2020. (Photo: P.G. Moore)

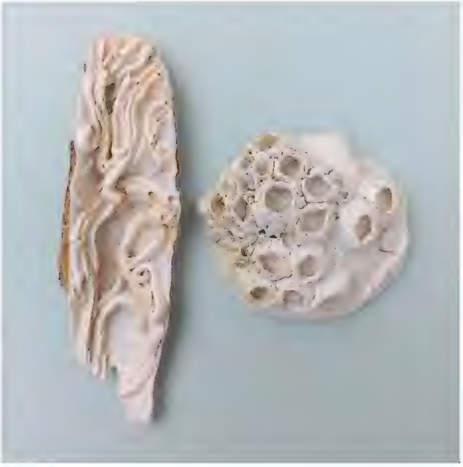

Fig. 5. Fragment of razorshell (*Ensis* sp.) shell (left) with inner surface fouled by *Spirobranchus triqueter*, and a right valve of *Dosinia exoleta* (right) fouled with *Balanus crenatus*. Both shells from South Fintray Bay, Isle of Cumbrae, 27th June 2020. (Photo: P.G. Moore)

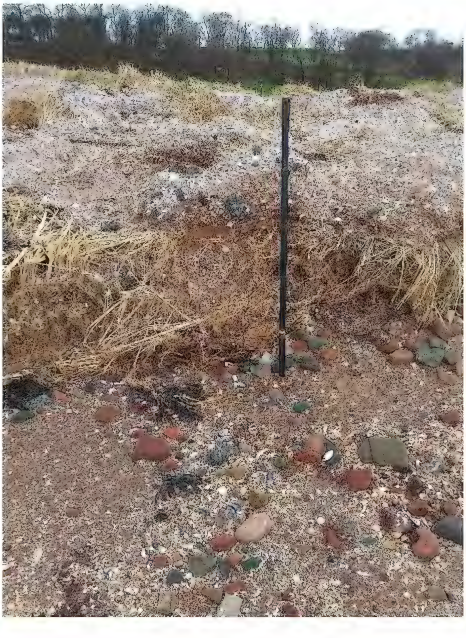

Fig. 6. The high-shore, storm-created berm feature at Ballochmartin Bay, Isle of Cumbrae, 7th February 2021. The pole is 95 cm tall. (Photo: P.G. Moore)

RESULTS

Table 1 shows the physical characteristics of the three sites investigated and Figs. 2-4 and 6 their appearance. Prevailing winds are south-westerlies (215°). Table 2 shows the composition of the surficial dead shells recovered from the strand-lines at the three sites investigated both during summer (June 2020) and winter (February 2021) seasons. Clear differences are apparent between the relative contributions of different species to the shell accumulations at the three sites investigated in summer. The Ballochmartin Bay material was dominated by common cockle (*Cerastoderma edule*), common mussel (*Mytilus edulis*) and common periwinkle (*Littorina littorea*) shells, reflective of the shallow expanse of sandy sediments in the shallow bay, interrupted by permanent boulders in the mid- to low-shore. The site at Stinking Bay was dominated by shells (*L. littorea)*, also associated with the sheltered aspect of that site and its extensive rocky platform shore. The South Fintray Bay site was dominated by larger, heavier shells: a mixture of limpets (*Patella vulgata*) and offshore bivalves: rayed artemis (*Dosinia exoleta*) with plentiful broken razorshell (*Ensis* spp.) valves, indicative of the energetic sea conditions impinging on this site.

Recovered shells were mostly damaged. Bivalves were almost universally disarticulated and often greatly fragmented. The most fragile and vulnerable-to-damage bivalves were *M. edulis* shells. The summer strand-line shell sand at Ballochmartin Bay was substantially composed of comminuted *M. edulis* shell debris together with undamaged disarticulated *C. edule* valves. Brittle *Ensis* spp. shells were also substantially fragmented (notably at the South Fintray Bay site). Valve fragments (both outsides and insides) of sublittoral species from offshore (like *Ensis* spp., *D. exoleta* and blunt gaper (*Mya truncata*) were often fouled by calcareous epifauna: barnacles (*Balanus crenatus*) and serpulid tubeworms (*Spirobranchus* sp.) (Fig. 5), indicating that they had lain exposed on the seabed for some time before being thrown onto the beach during storms). The most intact valves of bivalve species were of robust and more-rounded shaped species like *C. edule,* pullet carpet shell (*Venerupis pullastra*)*,* branded venus (*Clausinella fasciata*)*,* trough shells *Spisula* spp. and *D. exoleta.*

Regarding gastropods, the damage to limpet shells (*Patella vulgata*) depended on size. The largest shells were typically undamaged. The tall, thick shells of the largest specimens betokened an origin high on the rocky shore (Wigham & Graham, 2017), and so these would not have been carried far from their point of origin. Smaller limpets, with thinner, flatter shells emanating from lower down the shore, where growth conditions were more amenable, often had missing apices, giving the appearance of halos. *L. littorea* shells had spires missing and broken lips, some were "rotten" with worm holes made by the polychaete *Polydora ciliata.* Some of the larger gastropod shells (red whelk (*Neptunea antiqua*), *B. undatum,* pelican's foot (*Aporrhais pespelecani*)) were often reduced to the columella with only a section of the body whorl remaining. Most intact were the more robust, globular shells of flat periwinkles (*Littorina obtusata* and *L. fabalis*). Top shells (*Gibbula* spp.) too, being of a squat body form, were more often reasonably intact except often the periostracum was abraded away to expose the underlying shiny nacreous was the comparative rarity of dog whelk (*N. lapillus*)

BALLOCHMARTIN BAY	(Summer)		(Winter)	
Littoral species	Number	Dry weight (g)	Number	Dry weight (g)
Patella vulgata	13 (7)	17 (5)	4 (2)	6 (2)
Littorina littorea	30 (16)	28 (9)	75 (42)	77 (24)
L. saxatilis	1 (0.5)	<1	-	-
L. obtusata	18 (10)	8 (3)	34 (19)	19 (6)
L. fabalis	4 (2)	1 (0.3)	2 (1)	2 (1)
Gibbula cineraria	7 (4)	5 (2)	5 (3)	3 (1)
G. umbilicalis	1 (0.5)	1 (0.3)	-	-
Nucella lapillus	2 (1)	2 (1)	5 (3)	9 (3)
Buccinum undatum (i)	1 (0.5)	<1	-	-
Mytilus edulis (fr)	-	65 (21)	-	34(11)
Cerastoderma edule (v)	92 (49)	162 (52)	44 (24)	129 (41)
Venerupis pullastra (v)	4 (2)	3 (1)	1 (0.6)	6 (2)
Sublittoral species				
Aporrhais pespelecani	1 (0.5)	<1	-	-
Buccinum undatum	-	-	1 (0.6)	20 (6)
Neptunea antiqua	1 (0.5)	8 (3)	-	-
Ensis sp. (fr)	-	8 (3)	-	4 (1)
Clausinella fasciata (v)	3 (2)	1 (0.3)	-	-
Macoma balthica (v)	1 (0.5)	<1	-	-
Spisula solida (v)	8 (4)	5 (2)	9 (5)	8 (3)
S. subtruncata (v)	1 (0.5)	<1	-	-
Total	188 (100)	314 (100)	180 (100)	317 (100)

SOUTH FINTRAY BAY	(Summer)		(Winter)	
Littoral species				
Patella vulgata	106 (40)	336 (40)	46 (50)	158 (40)
Littorina littorea	86 (32)	81 (10)	24 (26)	35 (9)
L. saxatilis	1 (0.3)	<1	3 (3)	1 (0.3)
L. fabalis	2 (0.6)	<1	1 (1)	<1
Gibbula cineraria	17 (6)	8 (1)	7 (8)	9 (2)
Nucella lapillus	18 (7)	33 (4)	4 (4)	6 (2)
Cerastoderma edule (v)	1 (0.3)	6 (0.7)	-	-
Venerupis pullastra (v)	6 (2)	28 (3)	-	-
Sublittoral species				
Buccinum undatum (fr)	5 (2)	35 (4)	1(1)	26 (7)
Neptunea antiqua	3 (1)	21 (2)	-	-
Ensis sp. (fr)	-	158 (19)	-	109 (27)
Mya truncata (v)	1 (0.3)	11 (1)	-	-
Dosinia exoleta (v)	14 (5)	122 (14)	6 (7)	53 (13)
Cerastoderma edule (v)	1 (0.3)	6 (0.7)	-	-
Total	267 (100)	845 (100)	92 (100)	398 (100)

STINKING BAY	(Summer)		(Winter)	
Littoral species				
Patella vulgata	15 (5)	17 (9)	16 (40)	12 (39)
Tectura virginea	1 (0.4)	<1	-	-
Littorina littorea	170 (60)	87 (45)	8 (20)	7 (23)
L. obtusata	32 (11)	13 (7)	3 (8)	1 (3)
L. saxatilis	5 (2)	<1	-	-
L. fabalis	21 (7)	9 (5)	2(5)	<1
Gibbula cineraria	12 (4)	5 (3)	-	-
G. umbilicalis	1 (0.4)	<1	4(10)	2(6)
Nucella lapillus	15 (5)	5 (3)	4(10)	3(10)
Mytilus edulis (fr)	2 (1)	2 (1)	3(8)	3(10)
Cerastoderma edule (v)	1 (0.4)	13 (7)	-	-
Venerupis pullastra (v)	1 (0.4)	14 (7)	-	-
Sublittoral species				
Ensis sp. (fr)	4 (1)	6 (3)	-	2(6)
Dosinia exoleta (v)	1 (0.4)	19 (10)	-	-
Clausinella fasciata (v)	4 (1)	3 (2)	-	-
Total	285 (100)	193 (100)	40(100)	31(100)

Table 2. Species composition (% of sample in parentheses, rounded up) of surficial strand-line dead-shell accumulations at three sites on Isle of Cumbrae, Scotland in summer and winter (fr = fragments; i = immature; v = valves).

layer. What was immediately noticeable, considering their abundance on the rocky shores locally, however, shells and the absence of crustacean remains. It should be noted, however, that disarticulated barnacle plates were not retained on the sieve mesh used. Smaller gastropods like rough periwinkle (*Littorina saxatilis*), although abundant on mid- to high-shore rocks locally, were not retained in any numbers by the sieve mesh used either. All these materials will, of course on the first sampling, have accumulated over a considerable period of time.

Samples were re-taken in February 2021 after a lengthy period of strong easterly gales during the first week of February, during which time gusts to 60 knots were recorded locally. The huge *Valaris* DS4 drill ship, berthed at Hunterston jetty opposite the island, snapped its moorings on the evening of 2nd February and was only fifteen minutes from being wrecked on Cumbrae before its anchors thankfully held (Corral, 2021). The appearance of the upper shore at the Ballochmartin Bay site was considerably changed by these storms with a tall vertical berm (height variously 0.5 to >1 m) of shell-sand thrown-up among the supralittoral vegetation (Fig. 6) together with considerable kelp and wrack material (*Laminaria* spp. and *Fucus* spp.) cast-up around the high-tide mark. *M. edulis* shells especially, being relatively fragile, were markedly comminuted, the most intact shell valves being of the most robust species (*L. littorea*, *B. undatum*, *C. edule*). There was no increase in sublittoral species apparent, apart from a single large adult *B. undatum* shell.

At South Fintray Bay, the winter collection was again dominated by robust shells (*P. vulgata*, *L. littorea*, *Ensis* spp. fragments, *D. exoleta*), with a high proportion of the larger bivalve shell valves (*D. exoleta*, *Ensis* spp.) heavily fouled on their concave surfaces with serpulid tubeworms (*Spirobranchus* sp.). In both the summer and winter collections from this site a large proportion of broken fragments of robust bivalve shells (not censused) was present. *M. edulis*, however, was not in evidence, either as fragments or intact valves. The winter collection at Stinking Bay was dominated by gastropod shells (notably *L. littorea*), although a substantial proportion of this species' shells was too small to be retained by the sieve, as compared with the summer sample. The shells of *P. vulgata* were notably smaller than those from the South Fintray Bay site.

DISCUSSION

On an island, differing site topography, aspect and degrees of fetch-dependent wave action will impact onshore given different offshore bathymetric conditions, ground characteristics and hence faunal composition. Frey & Dörjes (1988) contrasted the effects of fair- and foul-weather on shell accumulations on a Georgia, U.S.A beach and highlighted the role of longshore (parallel to the shore) transport (see Lamont (1945) regarding beach material in the Clyde Sea Area). Longshore transport of shells will be of lesser importance on small local pocket beaches, with strand-line accumulations of entrapped dead shells reflective of adjacent living assemblages.

The predominant winds in the northern hemisphere are those from the south-west and the north-east (Lamont, 1945). Smith (1986) stated that "the Prestwick [Ayrshire] wind rose [see his Fig. 2] displays only moderate bias towards wind directions between west (260°–280°) and south (170°–190°) for it is clear that easterlies are also well able to reach the coast here," and that "westerlies are funnelled up the Clyde estuary" and "most of the gales are from the west". In his Table 1, Smith (1986) reported that the average annual maximum gust speed for Millport, Isle of Cumbrae was 68.9 knots. Of the three Cumbrae sites investigated, therefore, that most prone to rough seas from the south-west quadrant would be the South Fintray Bay site. That more-or-less west-facing site, adjacent to the deep water of the Main channel between the islands of Bute and Cumbrae, accounts for the prevalence of deeper-dwelling offshore species in the strand-line accumulations there, given wave refraction effects (*cf.* Moore, 1985, Table 2). The fact that easterly gales, although less frequent, can still on occasion generate high seas at Ballochmartin Bay resulted in the comminution of fragile *M. edulis* shells there, and have had other reported ecological effects (Moore, 2005). The more robust shell valves of *C. edule* (see Wilson, 1967; Farrow, 1974) fared better at Ballochmartin Bay long-term, so the superficial appearance of the strand-line death assemblage of molluscan shells there, unsurprisingly, varied according to prevailing weather events.

Although only occasional live native oysters (*Ostrea edulis*) are today to be found on Ballochmartin Bay, in the nineteenth century the bay supported a thriving population (Moore, 2020). Oyster shells are very robust, as witness their prevalence in prehistoric shell middens (see Introduction) and in archaeological sites from Roman to Mediaeval times (Winder, 1993). It is surprising therefore that no oyster-shell remains were discovered in the strand-line shell accumulations at Ballochmartin Bay. Since this could be due to only surficial samples being taken, a limited excavation (to double spade depth) was made in the supralittoral vegetation abutting the strand-line to check for buried oyster shells: none was discovered. There are biological agencies, like rabbit burrowing activity at the site (Moore, 2004), that can redistribute material but wind-blown sand and wave action during winter storms will have the biggest impact. It is often the case that easterly storms in winter lift beach sand, gravel and drift seaweed onto the adjacent coastal road at this site, so a century of deep burial could have obliterated the historical contribution of oyster shells.

Shells of sublittoral fringe populations of *Ensis* spp. may arrive onshore as a result of predation at lowest tides by herring gulls (*Larus argentatus*) (Moore, 2020). Mortality of offshore infaunal bivalve molluscs has also been recorded caused by harmful phytoplankton blooms (red tides) caused by dinoflagellates (Griffith *et al.*, 2019). I recall seeing an extensive stranding of *Ensis* spp. shells, along with burrowing heart urchins

(*Echinocardium cordatum*), washed-up along the beach at Fintray Bay many years ago (date unrecorded); another biological agency generating shell debris. Red-tide impacts can be widely detrimental to marine life; Jones *et al*. (1982) reported a red-tide killing pond-reared salmon in local sea lochs.

Moore (1985) compared the shell shape of fossil *N. lapillus* from the raised beach near Shell Hole, Cumbrae (OS Grid ref. NS15085416), a site to the south of the present South Fintray Bay site, with data on the adjacent modern strand-line molluscan death assemblage (his Table 2). Some 16.6% of the modern death assemblage from Shell Hole (sampled in 1983), a more exposed site, were *N. lapillus*. The general paucity of dogwhelk shells in the samples from all three sites here reported, chimes more with the fossil findings (2.6%) of Moore (1985) and comments by Robertson (1888), the latter noting that “post-Tertiary beds of the Clyde … contain very few examples of this shell” (but note Robertson, 1877) and could relate to that species' habit of aggregating in rock clefts and crevices, especially during winter (Feare, 1971) and, by such means, being able to avoid or resist removal by damaging wave action (note also Burrows & Hughes, 1989).

Some of the shell fragments of both bivalves (*M. edulis*) and gastropods (*L. littorea*) had holes drilled into them by *N. lapillus,* betokening dogwhelk predation as the proximate reason for their mortality. Limpets fall prey to crabs, fishes and starfish at high tide and to birds like oystercatchers (*Haematopus ostralegus*) at low tide. Pettitt (1975) has comprehensively reviewed the predators of *Littorina* spp. and his findings have a wider relevance for other rocky-shore gastropods and will not be rehearsed here. Those damaged *L. littorea* shells with missing spires or broken lips probably resulted from predation by the shore crab *Carcinus maenas* (Hughes & Elner, 1979) and Warner (1997) has examined the role played by the shell-burrowing polychaete *Polydora ciliata* or the boring sponge *Cliona celata* in weakening the shells of *L. littorea*. Thus biological agencies probably supply the empty coiled gastropod shells and may be secondarily re-distributed by hermit crabs (Frey & Dörjes, 1988). Regarding limpets, the hydrodynamics of the limpet body shape render them well-adapted to survive physical wave pounding (Denny, 2000). Once loose on a rocky shore, however, small empty limpet shells will be prone to waves smashing them against rocks, the shock to the apex resulting in breakage and the halo-shape "skirt" being the result. It is unlikely that wave stress alone would dislodge limpets. Even such small clinging amphipod crustaceans as *Apohyale prevosti* (as *H. nilssoni*) were not dislodged from channelled wrack (*Pelvetia canaliculata*) tufts by an onshore Force 9 westerly gale impinging on a high-shore site near to the South Fintray site (Moore, 1977).

The impact of seasonality (summer *vs.* winter) on strand-line deposits of dead shells thus depended on site aspect and the impact of particular storms. The longevity of different species' shells in the deposit will depend on their relative robustness, something that can be enhanced by calcareous epifauna (e.g. serpulid tubeworms on *D. exoleta* valves) or degraded by shell-boring organisms. Strandings of shells of sublittoral species reveal the impact of past storm events. Strand-line shell accumulations are thus episodic, time-averaged records of past energetic (particularly extreme) sea conditions whose history will stretch back decades and millennia. Storm surges in the Firth of Clyde are not unusual. Between 1985 and 2014, the Millport tide gauge recorded 92 surge events that exceeded 1 m (Sabatino *et al*., 2016). Hickey (2001) has reported in detail on one such storm's impact across Scotland. Both in the U.K. (Long & Wilson, 2007) and elsewhere (Kitamura, 2018), tsunami effects represent an extreme case in point. Taphocoenoses, then, are incipient thanatocoenoses. The relative abundance of littoral/sublittoral species in modern death assemblages finds explanation in environmental correlation and facilitates habitat and climate reconstruction of thanatocoenoses (*cf.* Norton, 1967, 1970; Boyd, 1982; Peacock, 1989, 1993; Tyler & Kowalewski, 2017).

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Daniel Alexander Boyd 1855-1928: a formidable amateur Scottish mycologist

R. Watling

26 Blinkbonny Avenue, Edinburgh EH4 3HU

E-mail: caledonianmyc@blueyonder.co.uk

ABSTRACT

Daniel Alexander Boyd, an amateur naturalist who came from West Kilbride, Ayrshire, Scotland, made considerable contributions to Scottish mycology but has been largely forgotten. In this paper, his life, and in particular his natural history activities, are outlined. To illustrate his achievements, an account of his contribution to knowledge of leaf and stem microfungi of the genus *Phyllosticta* in Scotland is provided.

INTRODUCTION

The aim of this paper is to draw attention to a largely forgotten amateur mycologist – D.A. Boyd – who made an outstanding contribution to Scottish natural history, mainly in the field of microfungi. A short biography is provided and, to give an indication of his scientific achievements, this is followed by an annotated list of all the Scottish microfungi found by him that have been assigned to the widespread and very speciose genus *Phyllosticta*.

Most of the biographical information provided below was obtained from Johnstone (1931) and Ramsbottom (1929, 1963). He is the subject of a short entry in the reference work of Ainsworth (1996), which regrettably misreports his year of birth.

DAVID ALEXANDER BOYD – THE MAN

David Alexander Boyd was a son of the manse, born in 1855 in West Kilbride, Ayrshire, Scotland, this village being the locality of many of his collections. In 1912 he moved to Saltcoats, Ayrshire, another locality of his collections, and died there in 1928. He qualified as a Writer to the Signet (a variety of solicitor) but never practised his profession and he was best known in his time for his natural history activities, especially his almost fanatical field collecting, which saw him venturing into every nook and cranny: "Dirty hands with grubbing – and he could grub like a terrier – among leaves, wet feet with wading through boggy places, torn clothes with scrambling through thorny bushes, and bruises from falls in climbing steep or slippery places, what did it matter so long as he got what he was seeking?" (Johnstone, 1931). At first he took a great interest in both archaeology and general natural history, especially ferns, mosses and flowering plants. He then turned his attention first to larger fungi and later to microfungi, because he noticed how meagre the records of these were (Johnstone, 1931). He served as President of the Cryptogamic Society of Scotland before it was disbanded in 1923 and published many records of fungi (eg. Boyd, 1913) especially in the society's Annual Reports (e.g. Boyd, 1913). He also published papers on various aspects of natural history in the *Transactions of the Natural History Society of Glasgow* and its successor *The Glasgow Naturalist*. The subjects of these papers included his findings for West Kilbride on plants and animals, as well as microfungi. He was editor of *The Glasgow Naturalist* (with John Paterson) from 1909 to 1914.

Boyd led many excursions for the Cryptogamic Society and for many of the natural history groups of which he became a member. It was reported that, although at first shy, he was eager to help anyone (Johnstone, 1931). He was president of the Natural History Society of Glasgow and during 1900-1901 he was a member of the organising committee for the proposed British Association for the Advancement of Science meeting for which he prepared lists of microfungi and certain arthropod groups in *The Fauna, Flora and Geology of the Clyde Area* (Boyd, 1901a,b,c). He later prepared a paper on physical features influencing the occurrence of fungi for the British Association Handbook for the 1928 Glasgow meeting (Boyd, 1928).

Boyd collected microfungi extensively and intensely, particularly in the Ayrshire area of Scotland, and continued to collect almost until his death. He did not generally collect any further afield, except apparently on forays organised by the Cryptogamic Society of Scotland and local organisations where his keen eye was helpful in spotting little known species, such as the leaf fungus *Phyllosticta* erysimi Westend. found by him in Perthshire on garlic mustard (*Alliaria petiolata*) (Grove, 1935). His finds resulted in many published articles and added many new species to the British list, some not found since. West Kilbride and the surrounding settlements offered a wide range of different habitats and therefore host plants. West Kilbride was a weaving village with many associated activities, whereas nearby Stevenston had an industrial history of coal-mining and chemical industries, which left waste areas and brown sites where fungi could be sought.

It is suspected that Boyd identified his collections only from the external appearance of their fruiting structures and of the host, and rarely used a microscope to investigate further, e.g. to measure the conidia (asexual spores) or development of the conidiomata (structures that contain conidia), which is admittedly an exceedingly difficult task even with the best of material and of microscopes. His forte as a naturalist was his ability to identify vascular plants and recognise the fungi growing on them. He must have had a very retentive memory. With respect to his ability to to find microfungi, Ramsbottom (1929) described Boyd as "our best field-man in this line". Over many years, especially latterly after retirement, the present author has tried to follow Boyd in his ability to spot microfungi but has been miserably unsuccessful, though that might be partly because in more recent times air pollution has adversely affected these foliicolous fungi.

Boyd sent his collections for identification or confirmation to Annie Lorrain Smith, a mycologist (best known for her contribution to British lichenology: Ainsworth, 1996) in the British Museum who also hailed originally from south-west Scotland, and to J.B. Grove at Birmingham Municipal Technical School. Both of these sets of specimens are now in the Herbarium at the Royal Botanic Gardens, Kew. Unfortunately only two of Boyd's specimens have been found in the fungarium in the Royal Botanic Garden, Edinburgh, which he himself created, *viz. Venturia johnsonii* (Berk. & Br.) Sacc. (now *Venturia maculiformis* (Desm.) Winter; Venturiaceae: Venturiales) and *Sporomega degenerans* (Kunze) Corda (Rhytismataceae: Rhytismatales) growing on bog whortelberry (*Vaccinium uliginosum*). He apparently never collected at the Edinburgh Botanic Garden.

Several taxa have been named after, or recognise, Boyd, including: *Coccomyces boydii* A.L. Sm. (Ostropocaceae: Rhytismatales), collected by Boyd from bog-myrtle (*Myrica gale*), Killin, Perthsire (Smith & Rea, 1907); discussed by Dennis (1968) and Sherwood (1980); *Helotium marchantiae* (Berk.) Fr. *var. conocephali* Boyd, found by Boyd on the liverwort *Conocephalum conicum*, Dalry, Ayrshire (Smith, 1907) and now placed in the recently recognised genus *Bryoscyphus* (Kirk & Spooner, 1984) as a distinct species *B. conocephali* (Boyd) Spooner (Helotiaceae: Helotiales); *Orbilia boydii* A.L. Sm. & Ramsb. 1913, found by Boyd on stems of blaeberry (*Vaccinium myrtillis* L.), Beith, Ayrshire (Smith & Ramsbottom, 1913), and now called *Pezicula myrtillina* P. Karst. (Dermateaceae: Helotiales); *Ascochyta boydii* Grove (Didymellaceae: Pleosporales) (Grove, 1918), found by Boyd on water plantain (*Alisma plantago-aquatica*), Stevenston, Ayrshire; its taxonomy has remained unchanged.

Smith (1917) named a genus after Boyd - *Boydia* - for the species *B. remuliformis* found by Boyd on holly (*Ilex aquifolium*) in West Kilbride. This is unfortunately a junior synonym of *Vialaea insculpta* (Fr.) Sacc. (Vialaeaceae: Xylariales) and is discussed by Dennis (1968). It has also been found on Mull (Henderson & Watling, 1978).

Boyd personally described only two species – *Bryoscyphus conocephali*, as noted above, and *Orbilia marina* (Phill.) Boyd, occurring on decaying fronds of seaweed (Boyd's description was reported in Smith, 1907), which was subsequently renamed *Laetinaevia marina* (Boyd) Spooner (Kirk & Spooner, 1984), and then *Calycina marina* (Boyd) Rämä & Baral (Pezizellaceae: Helotiales) (Baral & Rämä, 2015).

BOYD'S CONTRIBUTION TO SCOTTISH MYCOLOGY AS EXEMPLIFIED BY *PHYLLOSTICTA*

To give an indication of the importance of Boyd as a mycologist, his contribution to knowledge of the genus *Phyllosticta* in Scotland is now outlined.

Phyllosticta is a genus of coelomycetes - an artificial taxonomic group of fungi imperfecti (which lack a known sexual state) that produce conidia inside a cavity - the conidioma (pl. conidiomata). *Phyllosticta* species are distinguished by their thin-walled conidiomata and imperceptible or shortened conidiophores (fungal hyphae that carry conidia) called pycnidia. They are mostly plant pathogens and are responsible for numerous diseases, including leaf and fruit spot (Fig. 1), some of which are of significant economic importance (Wikee *et al*., 2013). Kirk *et al*. (2008) estimated that there are around 90 well-documented and confirmed *Phyllosticta* species. As with other fungi imperfecti, some *Phyllosticta* species have been found to be asexual stages in the life-cycle of species that have a known reproductive stage (teleomorph), in which case their name is changed to that of the teleomorph.

The following is an annotated list of all Scottish microfungi collected by Boyd during his excursions that have been identified as *Phyllosticta* species. All the records can be found in Grove (1935). References are also given to the descriptions by Grove or A.L. Smith (with or without J. Ramsbottom) of new taxa based on Boyd's specimens; these taxa are indicated below by an asterisk. West Kilbride is abbreviated to WK.

Phyllosticta acetosellae A.L. Smith & Ramsb. On sheep's sorrel (*Rumex acetosella*), Ayrshire and Lanarkshire (Smith & Ramsbottom, 1912); this is now *Didymella acetosellae* (Smith & Ramsb.) Qian Chen & L. Cai.

P. aegopodii Allesch. On ground elder (*Aegopodium podagraria*), Renfrewshire, Ayrshire and Lanarkshire; now known to the asexual stage of *Mycosphaerella aegopodii* Pot. (Mycosphaerellaceae: Mycosphaerellales).

P. ajugae Sacc. On living leaves of bugle (*Ajuga reptans*); recorded by Grove (1935) only as collected in Ayrshire.

P. angelicae Sacc. On fading and living leaves of wild angelica (*Angelica sylvestris*), Ayrshire; now considered to be the anamorph (asexual reproductive stage) of *Asteromella huubii* Ruszk.- Mich. (family *incertae sedis*).

****P. asperulae*** Grove. On fading and dead leaves of woodruff (*Galium odoratum*), Dalry, Ayrshire (Grove, 1922).

P. briardi Sacc. On living leaves of crab apple (*Malus sylvestris*), Stevenston, Ayrshire.

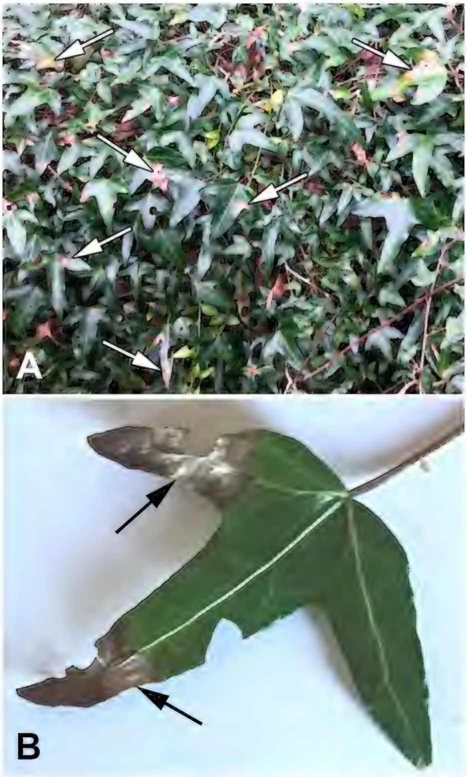

Fig. 1. *Phyllosticta hederae*. (A) Spots (arrows) on living leaves of ivy (*Hedera helix* 'Pedata') on garden wall, Edinburgh, Scotland, January 2022. (B) Dry spots of P. hederae on leaf of ivy shown in (A); these have circular except where broken by the leaf edge; the spots are dark at the margain and pale in the centre. (Photos: R. Watling)

P. carpathica Allesch. & Syd. On living leaves of the naturalised bell flower (*Campanula persicifolia*), Ayrshire; now *Ascochyta carpathica* (Allesch.) Keissl. (Didymellaceae; Pleosporales)

P. cornicola Rabenh. On leaves of dogwood (*Cornus alba*); noted by Grove (1935) only as collected in Ayrshire.

P. coryli Westd. On living leaves of hazel (*Corylus avellanea*); recorded by Grove (1935) only as collected in Ayrshire..

P. dahliicola Brun. On dead stems and petioles of *Dahlia* at Saltcoats, Ayrshire; now *Ascochyta dahliicola* (Brun.) Petr. (Didymellaceae; Pleosporales).

P. destructiva* var. *menyanthis Rabenh. On bogbean (*Menyanthes trifoliata*), Ayrshire; Grove (1935) thought this is really an *Ascochyta* sp.

P. ericae Allesch. On dead leaves of cross-leaved heath (*Erica tetralix*), WK.

P. erysimi Westend. On leaves of garlic mustard, Perthshire.

P. euonymi Sacc. On leaves of spindle (*Euonymus japonicus*), Ayrshire.

P. eupatorii All. On fading leaves of hemp agrimony (*Eupatorium cannabinum*), Ayrshire.

P. eximia Bubak. On fading leaves of marsh hawk's-beard (*Crepis paludosa*), Ayrshire and Renfrewshire; now *Asteromella eximia*.

P. forsythiae Sacc. On leaves of golden bells (*Forsythia suspensa*), Ayrshire; this is the very variable *Phoma exigua* (Bubak) Boerema (Didymellaceae).

P. fraxinicola Sacc. On leaflets of ash (*Fraxinus excelsior*), Argyllshire; this is really *Melomastia mastoidea* (Fr.) Schroeter (Pleurotremataceae; order *incertae sedis*), differing from *Phyllosticta* in the structure of the conidiophores, as Grove (1935) noted.

P. fuchsiicola Speg. On dead bark and stems of *Fuchsia* sp., WK; this could be one of the numerous *Fuchsia* cultivars, many based on hybridisation of the South American lady's ear-drop (*F. magellanica*), which is grown extensively in the west as it is hardy and withstands salty winds; as indicated by Grove (1935), the host substrate is unusual as *P. fuchsiicola* more commonly colonises the leaves; it is also recorded for the British Isles on *F. coccinea*.

P. funkiae Ferrarris. On leaves of plantain lily (*Hosta* sp.; referred to as *Funkia ovata*), Dalry. *Hosta* is a large genus with many cultivars grown in gardens. It is most likely that the species which acted as host to the *Phyllosticta* collected by Boyd was a cultivar of *H. undulata*.

P. gei Bres. On leaves of water avens (*Geum riviale*) and wood avens (*G. urbanum*), Ayrshire.

P. grossulariae Sacc. On living leaves of gooseberry (*Ribes uva-crispa*), Bute and Ayrshire; this is the asexual stage of *Mycosphaerella ribis* (Fuckel) Lindau (Mycosphaerellaceae: Mycosphaerellales).

P. hederae Sacc. & Roum. On dead spots on living ivy leaves (*Hedera helix*), Ayrshire (see Fig. 1).

P. helianthemicola Allesch. On dead leaves, sepals and petals of "*Helianthemum*", Perceton, Ayrshire; the host was presumably the common rock-rose (*Helianthemum chamaecistus*), other native species having a very restricted distribution and rarely planted outside their range.

P. hepaticae Brun. On *Anemone hepatica* (*Hepatica triloba*), WK; the host was undoubtedly an introduced plant, the species being of Eurasian distribution.

***P. heucherae forma sanguineae** Grove. On fading leaves of alum root (*Heuchera sanguinea*), WK; the form differs from the type (which was found in France) in the colour and size of the spots and in the spores being longer, narrower and curved (Grove, 1922).

P. hortorum Speg. On fading leaves of bittersweet (*Solanum dulcamara*), WK.

P. holosteae Allesch. On bleached leaves of bog stitchwort (*Stellaria alsine*), Kilwinning, Ayrshire.

***P. hydrocotyles** A.L. Sm. On leaves of marsh pennywort (*Hydrocotyle vulgaris*), WK (Smith, 1917).

P. impatientis Fautr. On living and fading leaves of wild balsam (*Impatiens noli-tangere*), Ayrshire.

P. lamii Sacc. On fading leaves of white dead-nettle (*Lamium album*), Stevenston, Ayrshire.

***P. lychnidina** Grove. On living leaves of red campion (*Lychnis dioica*), WK (Grove, 1918).

P. mahoniana Allesch. On fading leaves of Oregon grape (*Mahonia aquifolia*) Ayrshire; the host is a widely planted ornamental from Western North America.
P. marchantiae Sacc. On dead archegoniophores (components of female reproductive structures) of the liverwort *Marchantia polymorpha*, Kilwinning; *M. polymorpha* has recently been shown to be a complex of taxa.
P. oxalidis Sacc. On leaves of wood sorrel (*Oxalis acetosella*), Beith, Dalry (Ayrshire) and WK; Grove (1935) pointed out that the spots strongly resemble those of the coelomycete *Stagonospora hygrophila* Sacc. and there is a suggestion that it may have a *Mycosphaerella* teleomorph.
P. platanoidis Sacc. On fading leaves of cotyledons of sycamore (*Acer pseudoplatanoides*), WK; now *Asteromella platanoidis*.
P. polemonii A.L. Sm. & Ramsb. On fading leaves of "*Polemonii*", Ayrshire; though the specific host taxon is not given, *Polemonium caeruleum* (Jacob's ladder) is the native species (Smith & Ramsbottom, 1916).
P. potamogetonis Rostr. Recorded by Grove (1935) as *P. potamia* Cooke, on leaves of pondweed (*Potamageton* sp.), Ayrshire; the host species is not specified; the original fungus described by M.C. Cooke as *P. potamia* is the asexual stage of a smut fungus (*Doassansiopsis hydrophila* (Diedrich) Lavrov (Urocystidiales: Basidomycota). Grove reported that the spores of Boyd's collection were slightly constricted and gave signs of being 1-septate, which points towards an *Ascochyta* sp.
P. punctiformis Allesch. On fading leaves of red campion (*Silene dioica*), Largs, Ayrshire.
P. ranunculorum Sacc. & Speg. On fading leaves of fair maids of France (*Ranunculus aconitifolius*), Ayrshire; the host, being native to Central Europe, was presumably an introduced plant.
P. rhodorae (Cooke) Tassi. On living leaves of *Rhododendron* sp., Renfrewshire; no specific name is offered for the host species, the habit of indicating the genus alone being unfortunately widespread amongst mycologists; *P. rhodorae* was originally placed in *Phoma* but Grove (1935) commented that it was better placed in *Phyllosticta*.
P. ribicola Sacc. On red currant (*Ribes rubrum*), Seamill, Ayrshire; this (like ***P. grossulariae***: see above) is the asexual stage of *Mycosphaerella ribis*.
P. sambuci Desm. On living and fading leaves of elder (*Sambucus nigra*), Ayrshire; widespread in U.K.
P. scrophulariae Sacc. On fading and living leaves of figwort (*Scrophularia nodosa*), Ayrshire.
P. scrophularinea Sacc. On living leaves of water figwort (*Scrophularia aquatile*) and *S. nodosa*, Ayrshire.
P. teucrii Sacc. & Speg. On living on leaves of wood sage (*Teucrium scorodonia*), Ayrshire.
P. typhina Sacc. & Malcr. On tips of leaves of reed mace (*Typha latifolia*), Kilwinning.
P. ulmi Westd. On dead and fading leaves of elm (*Ulmus*: species not specified), Ayrshire.
P. umbilici Brun. On fading and dead leaves and stalks of pennywort (*Umbilicus rupestris*), Ayrshire.
P. valerandi Brun. On fading and living stems of brookweed (*Samolus valerandi*), Isle of Cumbrae.
P. valerianae Sm. & Ramsb. On leaves of valerian (*Valeriana officinalis*), Whiting Bay, Isle of Arran (Smith & Ramsbottom, 1915).

CONCLUSION

The above account of *Phyllostica* demonstrates how important Boyd's contributions were to Scottish, and British, mycology. Boyd collected specimens of 51 *Phyllosticta* species in Scotland, which included one form and six species new to science. The field data show that Boyd collected in a variety of habitats and it is therefore unsurprising that both himself and his clothing were damaged in this quest (as celebrated by Johnstone, 1931).

His influence extended not just to *Phyllosticta* and other coelomycetous "stem and leaf fungi", but also to those fungi that can be classified as "moulds", such as the plant pathogen genera *Ovularia* and *Ramularia*: for example, although Massee (1895) had described 30 British species in these two genera, Boyd increased the total to 53 for the Clyde area alone (Ramsbottom, 1929).

Although Boyd has been almost forgotten, the present author hopes that, by drawing attention to his contributions over a wide range of microfungi, he will eventually attain his rightful place in the hierarchy of Scottish mycology.

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Marine turtles and their barnacles from Scottish waters and adjacent seas

M. O'Reilly[1], A. Brownlow[2], M. ten Doeschate[2], D. Fenwick[3] & R. Penrose[4]

[1]Scottish Environment Protection Agency, Angus Smith Building, 6 Parklands Avenue, Maxim Business Park,
Eurocentral, Holytown, North Lanarkshire ML1 4WQ

[2]Scottish Marine Animal Stranding Scheme, Institute of Biodiversity, Animal Health & Comparative Medicine, College of Medical, Veterinary & Life Sciences, University of Glasgow, Glasgow G12 8QQ

[3]APHOTOMARINE, https://www.aphotomarine.com/

[4]British and Irish 'TURTLE' Database Manager, Marine Environmental Monitoring, Penwalk, Llechryd, Cardigan,
West Wales SA43 2PS

[1]E-mail: myles.oreilly@sepa.org.uk

ABSTRACT

The history of marine turtles in Scottish waters and adjacent seas is reviewed. The recording and reporting schemes for stranded marine animals in Scotland and the U.K. are highlighted. Detailed descriptions are provided of strandings of a loggerhead turtle (*Caretta caretta*) at Irvine, Ayrshire in December 2015, with numerous attached goose barnacles (*Lepas anatifera*) and a leatherback turtle (*Dermochelys coriacea*) at St. Cyrus, Aberdeenshire in January 2016, with several acorn barnacles (*Stomatolepas dermochelys*). A review of U.K. marine animal strandings reports revealed additional records of *L. anatifera* and *L. hillii*, from stranded loggerheads in Carmarthenshire in 2006 and in Cornwall in 2016 respectively, as well as another leatherback with *S. dermochelys* in Cornwall in 2018. The occurrence of lepadomorph and balanomorph barnacles on turtles is discussed including historical records from the U.K. and Ireland, and adjacent waters in the Mediterranean and the north-east Atlantic. Taxonomic confusion within the genus *Stomatolepas* is clarified. Other species of barnacle that might occur on turtles reaching the waters of the U.K. and Ireland in the future are discussed along with other exotic fauna that can accompany turtles. The impact of barnacles on turtles and how turtles remove attached epibionts is summarised.

INTRODUCTION

Whales, dolphins, or marine turtles washed up on Scottish shores are routinely examined under the Scottish Marine Animal Stranding Scheme (SMASS) (Brownlow *et al.* 2016). The occurrence of whale or turtle barnacles is poorly known in British waters, so these strandings offer an opportunity to examine and provide new information on these interesting epibiont fauna. Two relatively recent finds of unusual barnacles from turtles stranded in Scotland, and examined by SMASS, prompted this investigation and a review of current knowledge on turtles and their barnacles in the waters around the U.K. and Ireland.

MARINE TURTLES

Marine turtles are rare visitors to the shores of Britain and Ireland. Historically they have received scant attention as British subjects. Smith (1951), in his volume on the British amphibians and reptiles, stated that turtles do not properly belong to the British fauna and he provided only a brief account of the five species then known from British waters with a map depicting their stranding locations throughout Britain and Ireland. Records of marine turtles in British or Irish waters have usually been scattered in fisheries articles, naturalists' journals, or press reports and have only occasionally been collated (Taylor, 1948, 1963; Brongersma, 1972), with details of Scottish records gathered by Stephen (1953, 1961), Stephen *et al.* (1963) and McInerny & Minting (2016).

In the 1960s efforts were made to better inform fishing communities about marine turtles and to encourage reporting of sightings (Brongersma, 1967, 1968a). Leatherback turtles (*Dermochelys coriacea*) are the largest living turtle species. The largest leatherback so far recorded in the U.K. stranded on Harlech beach, Wales, in 1988. It measured almost 3 m and weighed 914 kg and is now displayed at the National Museum of Wales (Hanley *et al*., 2013). It is perhaps understandable that some previous turtle sightings of leatherbacks in Scottish waters, or elsewhere, have been mistaken for mythical beasts (Brongersma, 1968a,b,c). It is now known that the leatherback turtle is able to maintain an elevated body temperature in cooler northern seas (Frair *et al.*, 1972; Mrosovsky, 1980) and that it is an intentional summer migrant to British waters, in search of jellyfish on which it feeds (Davenport, 1998). Leatherbacks are the only turtle species able to maintain warm body temperatures in cold waters and this adaptation also allows them to dive to cooler waters of over 1,000 m depth in search of prey (Lovich & Gibbons, 2021). Hard-shelled turtles are not able to regulate their temperatures in the same way, hence should not normally occur in cooler British waters unless they have drifted there on currents. Therefore, the leatherback, at least, became regarded as part of the British fauna worthy of further monitoring and proper protection (Brongersma, 1982; Anon., 1984).

A Turtle Code advice sheet was produced by the Nature Conservancy Council in 1988 aimed at various seafarers. Scottish Natural Heritage (SNH, now NatureScot) undertook a review of marine turtles in Scottish waters (Langton *et al.*, 1996) and issued their own turtle code advice sheet (Davenport & Gaywood, 1997). A guide to the marine turtles in British and Irish waters was published by Gaywood (1997) and additional turtle codes were issued by the Cornish Wildlife Trust in 1997 and the Countryside Council for Wales (CCW) in 1998. A U.K. Marine Turtles Grouped Species Action Plan was produced by the U.K. Biodiversity Action Group (UKBAP, 1999) which proposed various actions on policy and legislation, species management and protection, and future research and monitoring. Thereafter, the Turtle Implementation Group was formed which comprised lead conservation agencies and research groups in the U.K. A review of turtle strandings in British and Irish waters was undertaken by Pierpont (2000) and subsequently a database of turtle records for the U.K. and Ireland was established (Pierpont & Penrose, 2002).

From 2001 marine turtles were included within the U.K. Cetacean Strandings Investigation Programme (CSIP) with information on stranded turtles included within CSIP annual reports (https://ukstrandings.org/csip-reports/). Turtle strandings in Scottish waters are investigated by SMASS and further information on Scottish marine mammal and turtle strandings is included in SMASS annual reports available online from 2009 (https://strandings.org/publications/). More comprehensive information, including distribution maps of all turtle strandings and live sightings for the U.K. and Ireland, has been separately collated since 2001 and is available in annual reports produced by Marine Environmental Monitoring (MEM) (www.strandings.com/). These include the first ever record from the U.K. or Ireland of an olive ridley turtle (*Lepidochelys olivacea*), which was found alive in the Menai Strait, Wales, in November 2016 (BBC, 2016c; Penrose & Gander, 2017). A second olive ridley was recently reported off Seaford beach, East Sussex (BBC, 2020). However, subsequent examination revealed this specimen to be a Kemp's ridley turtle (*L. kempii*). The British and Irish 'TURTLE' database now holds 2,881 records of sightings and strandings of turtles from 1748 to the end of 2021. An analysis of the long-term records of turtles around the U.K. and Ireland was undertaken by Botterell *et al.* (2020). A summary of the over one thousand records of turtles, from around the U.K. and Ireland over the last twenty-one years is provided in Table 1. On average there have been 50 turtle records per year. Of the 1,052 turtle records around 67% were leatherbacks, around 15% were loggerheads, and about 12% were unidentified. Kemp's ridley turtles, green turtles (*Chelonia mydas*), and olive ridley turtles represented only 3.9, 0.9, and 0.009% respectively.

A thorough review of current knowledge about marine turtles in Scottish waters is included in the volume *The Amphibians and Reptiles of Scotland* (McInerny & Minting, 2016). The authors provided detailed distribution maps of the turtles recorded from Scottish waters and indicate that from about 1750 to 2014 there were around 350 records of turtles in Scottish waters, including about 250 leatherbacks, 50 loggerheads, nine Kemp's ridley turtles, four green turtles and about 80 turtles unassigned to species. Only adult leatherbacks (length 1.8-2.9 m) appear to visit Scottish waters. Most leatherback sightings are between June and October and are live animals, though a number were found to have died following entanglement in fishing gear.

The distribution of leatherbacks in relation to their gelatinous prey was examined, for the Irish Sea by Houghton *et al.* (2006) and for the north-east Atlantic by Witt *et al.* (2007). The hard-shelled turtle species that occur in Scottish waters are usually juveniles, which are carried by currents from warmer seas. They are often found dead but many are still alive, albeit cold-stunned and consequently lethargic. Previous records of hawksbill turtles (*Eretmochelys imbricata*) from Scotland are considered erroneous (McInerny & Minting, 2016), and currently there is only a single confirmed record of a hawksbill turtle from the U.K. or Irish waters, caught in a herring net off Cork in 1983 (O'Riordan *et al.*, 1984; King & Berrow, 2009).

Country	**Leatherback**	**Loggerhead**	**Green**	**Kemp's Ridley**	**Olive Ridley**	**Unidentified**
Scotland	113	36	3	8		14
Ireland	227	45	1	3		22
England	254	56	2	17		84
Wales	115	22	4	13	1	12
Totals:	**709**	**159**	**10**	**41**	**1**	**132**

Table 1. Records of sightings or strandings of marine turtles in the waters around the United Kingdom and Ireland from 2001 to 2021.

Some historical Scottish turtle records include fascinating anecdotes (McInerny & Minting, 2016). In 1829 a live turtle (suspected loggerhead) was captured at Southerness, Dumfries and Galloway, and was sent to a hotel in Dumfries to make soup; in 1861 a turtle (suspected loggerhead) was captured alive at Rowardennan in Loch Lomond, presumably having swum up the River Leven. In 1959 a leatherback was captured in Kilbrannan Sound, Firth of Clyde, and was transported alive to Calderpark Zoo in Glasgow. It subsequently died, but a cast of the specimen is now in Paisley Museum and the head is held in the Kelvingrove Art Gallery and Museum, Glasgow (Reg. No. Z.1959.138.2).

The Kelvingrove Museum also has a cast of a leatherback found entangled in creel ropes in Luce Bay, Kirkcudbrightshire, in 1975 (Reg. No. Z.1975.118), and National Museums Scotland, Edinburgh hold a semi-modelled head of a leatherback collected from Annan, Dumfriesshire, in 1959 (Reg. No. 1959.49.1.1), and a full cast of a leatherback collected from Crail, Fife, in 1967 (Reg. No. NMS.Z.1967.81.1). The leatherback cast on display in the Hunterian Zoology Museum (Graham Kerr Building, University of Glasgow) was purchased in New York in 1916 and shipped across the Atlantic. In the midst of World War 1 this would have been a perilous journey for a replica turtle compared with the transatlantic migrations of its living counterparts in the wild.

TURTLE BARNACLES

Although poorly known by many naturalists, barnacles, with their highly transformed crustacean morphology, are an ideal case study for evolutionary biologists and they were extensively investigated over many years by Charles Darwin (Darwin, 1851, 1854; Stott, 2003; Jagt, 2020). It is advantageous for barnacles if they can attach to marine turtles. The turtle provides a mobile feeding platform with enhanced feeding currents and an absence of barnacle predators. However, the turtle has apparently little to gain and growth of barnacles or other epifauna impedes their motility and is a hindrance to be avoided. While considerable interest has been shown in turtles occurring in British and Irish waters, little has been published about the unusual barnacles that they sometimes host. The first Linnean Society synopsis of British Barnacles (Bassindale, 1964) does not mention any barnacles from turtles. However, the revised synopsis of the British barnacle fauna (Southward, 2008) has records of three sessile acorn barnacle species from turtles in British waters and cites a potential fourth species.

In the winter of 2015/16 two turtles stranded on Scottish shores within a month, each harbouring some unusual barnacles. This communication examines these new Scottish records of turtle barnacles and reviews some other recent records from England and Wales. Historical records of turtle barnacles from the U.K. and Ireland are considered along with other barnacles which might be expected on turtles entering British or Irish waters. Unless stated otherwise the scientific names used herein for barnacles and other species follow the World Register of Marine Species (WoRMS, https://www.marinespecies.org/).

Recent records of turtle barnacles

Many of the stalked (lepadomorph) or sessile (balanomorph) barnacles commonly found on turtles have cosmopolitan distributions and illustrated keys for their identification are provided by Monroe & Limpus (1979) and Zullo (1979). The lepadomorph barnacles attach to almost any floating objects, including turtles. Most of the balanomorph barnacles found on turtles are more specialised chelonophilic barnacles which occur only on turtle hosts.

On 5th December 2015, in the wake of Storm Desmond, a loggerhead turtle was washed ashore on Irvine beach in the Firth of Clyde, Scotland (M408/15 in SMASS database, National Reference number T2015/02). The turtle was found alive, but moribund, by participants from a nearby cycling event, and the British Divers Marine Life Rescue and Scottish SPCA were alerted. The turtle, a young female, 72 cm in length and weighing 28 kg, had a malformed right front flipper and was heavily infested by goose barnacles on the upper right side (Fig. 1). The turtle was transferred to the Scottish Sea Life Sanctuary at Oban for rehabilitation. The goose barnacles were removed but unfortunately the turtle died a few days later (Scottish Sea Life Sanctuary, 2015). The turtle was subsequently necropsied by SMASS and the cause of death was considered most likely to have been cold shock (Brownlow *et al.*, 2016).

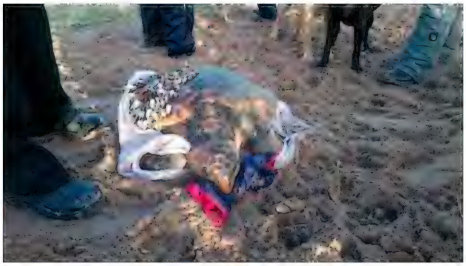

Fig. 1. Loggerhead turtle (*Caretta caretta*) (frontal view) stranded on Irvine Beach, Scotland, December 2015. (Photo: Andy Martin, SEPA)

Although the goose barnacles were not retained, various photographs show them *in situ* (BBC, 2015b; Penrose & Gander, 2016; Deaville *et al.*, 2016), (Fig. 2), or being removed by the sanctuary staff (Figs. 3 and 4). The goose barnacles can be identified from the photographs as *Lepas anatifera,* due to their relatively large size, their smooth shell plates (without obvious radial ridges), the narrow gap between the carina and scutum plates, and the absence of any rust-coloured band at the top of the peduncle (Broch, 1959; Southward, 2008). It can be estimated from the photographs and the turtle image with a scale shown in Brownlow *et al.* (2016) that the largest barnacles were around 10 cm long, and it

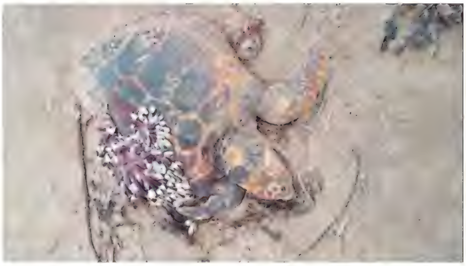

Fig. 2. Loggerhead turtle (*Caretta caretta*) (dorsal view) stranded on Irvine Beach, Scotland, December 2015. (Photo: Scottish SPCA)

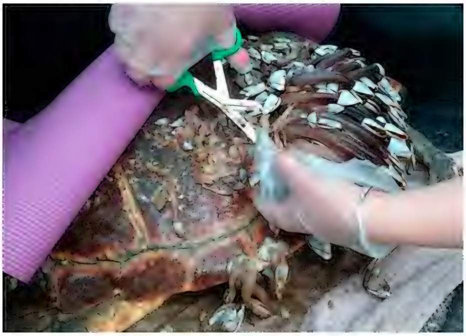

Fig. 3. Removal of goose barnacles (*Lepas anatifera*) from loggerhead turtle (*Caretta caretta*) from Irvine Beach, Scotland, December 2015. (Photo: Anna Price, Scottish Sea Life Sanctuary)

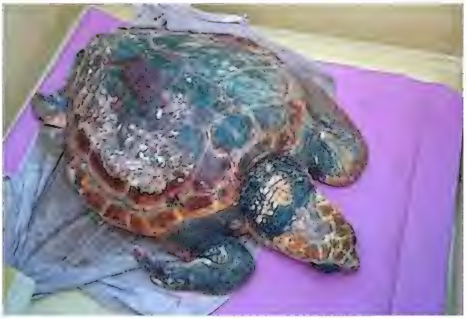

Fig. 4. Loggerhead turtle (*Caretta caretta*) from Irvine Beach, Scotland, after removal of goose barnacles (*Lepas anatifera*). December 2015. (Photo: Anna Price, Scottish Sea Life Sanctuary)

appears that around 80 to 100 were attached to the turtle.It is probable that the deformed flipper restricted the turtle's swimming manoeuvrability. This would have slowed movement of the turtle and may have limited its ability to abrade its shell on the seabed to remove growths. Hence, the goose barnacles were able to colonise and grow unhindered with these adding a burden to the turtle, further impairing its propulsion.

Barely a month later, on 8th January 2016, a leatherback turtle was found washed up dead on the beach at St. Cyrus Nature Reserve, Aberdeenshire (Anon., 2016, M24/16 in SMASS database, National Reference number T2016/01). The turtle was an immature male with overall length of 179 cm. It was removed from the beach and brought to the SMASS laboratory for examination (Fig. 5). The turtle weighed 209 kg and the subsequent necropsy suggested the cause of death was probably hypothermia (Brownlow *et al*. 2017; Penrose & Gander, 2017). It seems likely that the turtle may have been a victim of the then recent Storm Frank.

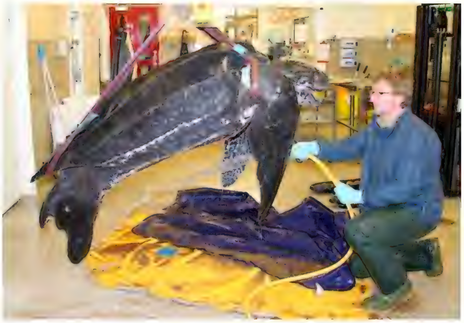

Fig. 5. Leatherback turtle (*Dermochelys coriacea*) from St. Cyrus, Scotland, being weighed prior to necropsy. (Photo: SMASS)

Twenty barnacles were found on the turtle, embedded in its skin. They were mostly located on or around the base of the front fins: eight ventrally between the base of neck and the base of left front fin (Fig 6a,b); one dorsally on base of same fin; five ventrally near base of right front fin; five dorsally behind base of same fin; and one ventro-laterally about half way along the body.

Thirteen barnacles were removed and preserved for closer examination (Fig. 7). They ranged in length from 7 to 11 mm and in thickness from 2.5 to 5 mm. The barnacles were bowl-shaped with a flat-topped aperture and a slightly inward curving shell with numerous small protrusions enabling them to embed in the host epidermis. These features readily allowed the barnacles to be ascribed to the genus *Stomatolepas,* and their host, and their location on the host, indicate they should be referred to *Stomatolepas dermochelys* as described by Monroe & Limpus (1979). The barnacles from the St. Cyrus leatherback are deposited in the National Museum of Scotland (Reg. No. NMS.Z.2022.9).

A review of the MEM annual reports (2001-2020) on turtle strandings and sightings in the U.K. and Ireland revealed two additional photographs of loggerheads infested with goose barnacles.

The first, in December 2006, a live loggerhead (length 84 cm, weight 36.5 kg) was found on Cefn Sidan Sands, Pembrey Country Park, Carmarthenshire, Wales, during strong south-westerly storms (Ref. No. T2006/39; Penrose & Gander, 2007). Most of the front left flipper

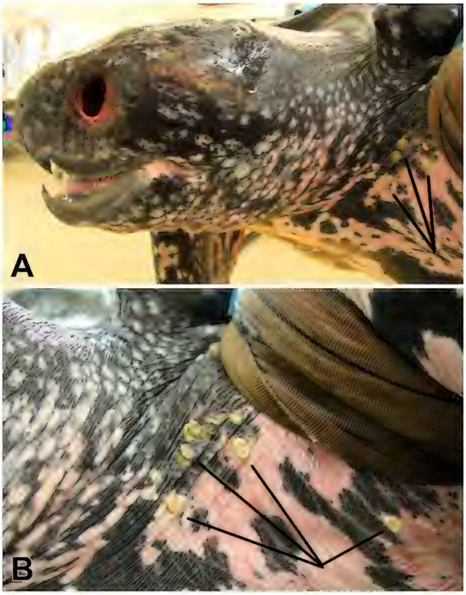

Fig. 6. Leatherback turtle (*Dermochelys coriacea*) from St. Cyrus, Scotland. (A) Acorn Barnacles (*Stomatolepas dermochelys*) (black lines) at base of neck. (B) Closer view of barnacles. (Photos: SMASS)

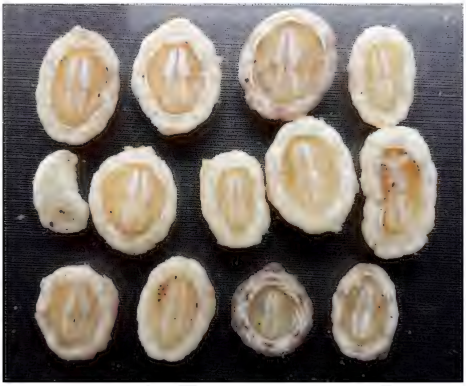

Fig. 7. Acorn Barnacles (*Stomatolepas dermochelys*) from St. Cyrus leatherback turtle (opercular view; longest barnacle to the right is 11 mm in length). (Photo: Myles O'Reilly)

was missing but this had healed indicating it was an old injury. Around six *Lepas anatifera* goose barnacles are shown attached at the rear on the underside of the carapace. This turtle was sent to the Weymouth Sea Life Centre for rehabilitation but died in February 2007. A post-mortem examination revealed lesions consistent with a severe chronic bacterial bronchopneumonia and tracheitis (Penrose & Gander, 2008).

The second, in January 2016, a juvenile loggerhead was found stranded alive, by David Fenwick, at Gwithian beach, Hayle, Cornwall, England (Ref. No. T2006/39; BBC 2016a,b; Penrose & Gander, 2017). There were around 30 goose barnacles attached to the rear of the carapace (Fig. 8) which were identified as *Lepas hillii.*

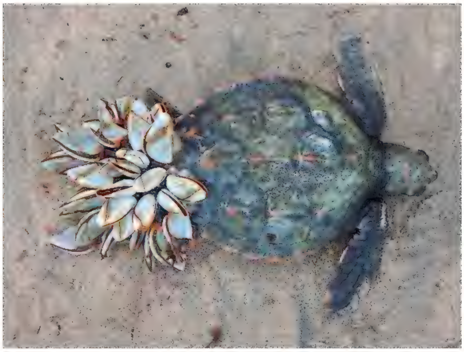

Fig. 8. Loggerhead turtle (*Dermochelys coriacea*) with goose barnacles (*Lepas hillii*), Gwithian Beach, Cornwall, England, January 2016. (Photo: David Fenwick)

As the Gwithian turtle was only around 20 cm long, and the individual barnacles each about 4-5 cm, the mass of goose barnacles must have been a significant impediment to its swimming. The turtle was rehabilitated at Newquay's Blue Reef Aquarium and the goose barnacles removed. It was subsequently repatriated by the Irish Navy close to the entrance to the Mediterranean.

In addition to the above records, in August 2018, a dead leatherback was found washed up near Marazion, Cornwall, England (Fig. 9, Ref. No. T2018/01; Wilkinson, 2018; Penrose & Gander, 2019). Nine sessile barnacles were removed from the underside of the front fins and have been identified as *Stomatolepas dermochelys.* An aperture view and underside view are shown here (Figs. 10 and 11) and further detailed images of these barnacles are available at the APHOTOMARINE website (https://www.aphotomarine.com/).

Turtles as hosts to lepadomorph goose barnacles

Although turtles are not mentioned as hosts of the lepadomorph goose barnacles in Southward's (2008) synopsis of British barnacles, their occurrence on turtles is not unexpected. The family Lepadidae contains several goose barnacles with cosmopolitan distributions in oceanic waters which attach to various floating objects. In British waters they are well known from ship hulls and flotsam (MBA, 1957; Evans, 2000) and are frequently cast ashore, especially on the western and south-western coasts of Britain and Ireland (Trewhella & Hatcher, 2015). They can be transported considerable distances by oceanic currents such as the Gulf Stream and North Atlantic Drift which bring them to British and Irish waters.

In 1977 a metal buoy found washed ashore near Dingle (south-west Ireland) with *L. anatifera* goose barnacles attached, also harboured some attached bivalves

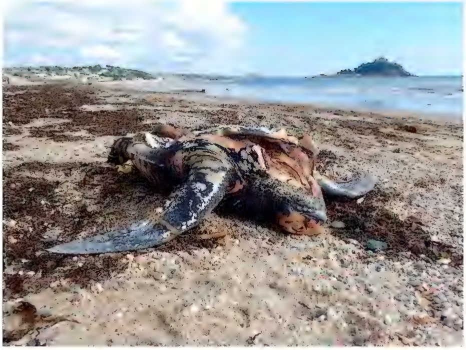

Fig. 9. Leatherback turtle (*Dermochelys coriacea*) at Gwithian Beach, Cornwall, England, August 2018. The underside has been opened for necropsy. (Photo: David Fenwick)

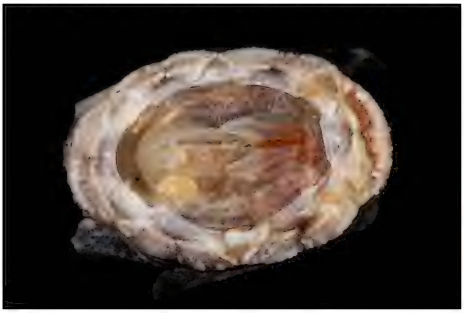

Fig. 10. Acorn Barnacle (*Stomatolepas dermochelys*) from leatherback turtle (*Dermochelys coriacea*), Marazion, Cornwall, England, August 2018 (opercular view from which the feeding cirri protrude). (Photo: David Fenwick)

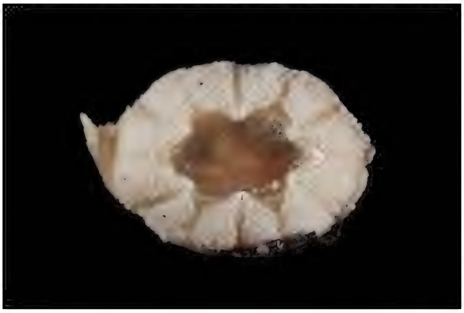

Fig. 11. Acorn Barnacle (*Stomatolepas dermochelys*) from leatherback turtle (*Dermochelys coriacea*), Marazion, Cornwall, England, August 2018 (underside view showing protrusions used to embed the barnacle into the turtle). (Photo: David Fenwick)

(*Brachiodontes exustus*) whose normal distribution is the coastal waters of the south-east U.S.A. and the West Indies (O'Riordan & Holmes, 1978). In November 2015 a large piece of rocket debris from Florida was recovered near Tresco, Scilly Isles, having acquired thousands of *L. anatifera* goose barnacles on its trans-Atlantic voyage (BBC, 2015a). The Faroe-Shetland current may carry goose barnacles onwards towards the west coast of Norway and up to northern Norway well above the Arctic Circle (Nilsson-Cantell, 1978). The proliferation of man-made flotsam may act as a habitat and vector for lepadid goose barnacles, and other rafting fauna, increasing their prevalence in oceanic waters (Minchin, 1996; Whitehead *et al.*, 2011; Kiessling *et al.*, 2015; Rech *et al.*, 2018; Mesaglio *et al.*, 2021). Images of numerous different transatlantic rafting species that have arrived in south-west England can be viewed on the APHOTOMARINE website (https://www.aphotomarine.com/trans_atlantic_rafting_species.html).

The natural habitat of most lepadid goose barnacles is floating objects such as tree trunks or branches, seed pods, coconuts, seaweed, pumice, feathers, cuttlebones, shells of Nautilidae squid, ram's horn squid (*Spirula spirula*) or of the violet sea snail (*Janthina janthina*), or floating corals (Thiel & Gutow, 2005; Whitehead *et al.*, 2011). However, they are opportunistic hangers-on and some also occur as facultative epibionts on whales (Clarke, 1966; Fertl & Newman, 2017), turtles (Epibiont Research Cooperative, 2007; Ten *et al.*, 2019) or sea snakes (Yamato *et al.*, 1996).

Occasionally goose barnacles are recorded from fish. The Plymouth Marine Fauna (MBA, 1957) cites a grey triggerfish (*Balistes capriscus*) from Devon which hosted *L. anatifera, L. hillii* and the striped goose barnacle *Conchoderma virgatum*. Since then, *L. anatifera* has been recorded from within the mouth of a sunfish (*Mola mola*) near the Azores (Barreiros & Teves, 2005) and *C. virgatum* has been found on a sunfish from Ireland (Cooper *et al.*, 1982), and attached to a grey triggerfish from Portugal (Ramos *et al.*, 2010). An Atlantic tripletail (*Lobotes surinamensis*) in the Adriatic Sea has been found hosting both *L. hillii* and *C. virgatum* (Dulčić *et al.*, 2015). In southern oceans goose barnacles sometimes attach to seals and penguins (Reisinger & Bester, 2010; Fertl & Newman, 2017).

In his review of turtle records from European Atlantic waters Brongersma (1972) cites five loggerhead and two Kemp's ridley turtles with unidentified goose barnacles attached from British, French, Dutch and Norwegian waters. One of the loggerhead turtles, from Jersey in 1950, was so laden with clusters of goose barnacles that the turtle floated upside down. A leatherback from Brittany in 1932 hosted two *C. virgatum* and one from Norway in 1956 had a few *Conchoderma* sp. on its upper and lower shell.

Studies of turtles in the Mediterranean indicate the occurrence of six goose barnacle species on loggerheads (*L. anatifera, L. anserifera, L. hillii, L. pectinata* and *C. virgatum*) with *L. hillii* present on more than half of stranded turtles on the eastern coast of Spain (Casale *et al.*, 2012; Domenèch *et al.*, 2015). Similarly, *L. anatifera* and *C. virgatum* have been found on loggerheads from the Canaries (Loza, 2011) and *L. anatifera* on Kemp's ridley turtles stranded on the coasts of Portugal and north-west Spain (Covelo *et al.*, 2016).

There are few previous published records of identified goose barnacles from turtles around the U.K. or Ireland. An adult loggerhead, which stranded in Skye, Scotland in December 1923, harboured a number of *L. hillii* attached to the underside of the carapace and one *C. virgatum* attached to the basal plate of one of the *L. hillii* (Ritchie 1924a,b). The striped goose barnacle, *C. virgatum*, has also been recorded from a leatherback in Irish waters (O'Connor & Bowmer, 1985). The 'TURTLE' database also has a record of a loggerhead (Reg. No. T1970/04), which stranded in Cornwall in November 1970, and had three *L. anatifera* on its underside.

The enigmatic nature of goose barnacles has generated some unusual myths (Lappo *et al.*, 2019). The occurrence of branches washed ashore, festooned with goose barnacles, led to the belief that they grew on trees and such trees were illustrated in medieval herbals. In addition, it was believed, in medieval times, that barnacle geese (*Branta leucopsis*), which vaguely resemble goose barnacles and mysteriously arrived on the shores of western Europe each winter, were actually spawned directly from the barnacles on these trees. This mythology is reflected in the species names *Lepas anatifera* and *L. anserifera* which translate as bearer of ducks and of geese respectively.

Turtles as hosts to balanomorph acorn barnacles

Among the balanomorph barnacles the superfamily Coronuloidea includes around 30 species worldwide which are mostly obligate epibionts on whales or turtles, but are also sometimes found on manatees, sea snakes, crocodilians, crabs and horse-shoe crabs (Young, 1991; Epibiont Research Cooperative, 2007; Hayashi, 2012, 2013).

Only three species of coronuloid barnacles are cited by Southward (2008) from turtles in British or Irish waters. In 1923 nearly 60 *C. caretta* were found on the aforementioned loggerhead from Skye, which also hosted two species of goose barnacle (Ritchie, 1924a,b). In July 1993 around 15 juvenile *Chelonibia testudinaria* were reported from a leatherback stranded in Gwynned, North Wales (Rees & Walker, 1993). *Chelonibia* barnacles are usually large and distinctly dome-shaped, up to 6 cm in basal diameter, and cement themselves to their host (Monroe & Limpus, 1979; Zardus, 2021). Both these species are widely recorded on turtles in the Mediterranean Sea and the Atlantic and Pacific Oceans (Hayashi, 2013).

There are several previous records of "*Stomatolepas elegans*" from leatherback turtles in British or Irish waters: in England from The Lizard, Cornwall, in July 1971 (Brongersma, 1972); in Scotland from Crail, Fife, in November 1967 and from Luce Bay, Kirkcudbrightshire, in September 1975 (Smaldon & Lyster, 1976); and in Ireland, from Cork in July 1971, from Malin Head in July 1973, and off Ventry, Kerry, in July 1976 (O'Riordan & Holmes, 1978). Barnacle specimens from The Lizard, Cornwall, were included in the type description of *S. dermochelys* Monroe & Limpus, 1979, and it now seems probable that all the "*S. elegans*" records cited above from leatherbacks in the U.K. and Ireland should also be referred to *S. dermochelys* as suggested by Hayashi (2013). Specimens cited above from Crail and Luce Bay are held in the National Museum of Scotland (Reg Nos. Z.1985.84-85).

In neighbouring waters *S. dermochelys* has been recorded from leatherbacks in Belgium (Haelters & Kerckhof, 1999; Haelters *et al.* 2001) and from the Netherlands (Holthuis, 1969). Live leatherbacks are known to enter Norwegian waters and have even been sighted within the Arctic Circle (Brongersma, 1972). A leatherback caught eight miles west of Skarvoy (60° 30' North) in 1965 hosted *S. dermochelys* (Smaldon & Lyster, 1976) as did one captured near Finnmark (~ 71° North) in 1997 (Carriol & Vader, 2002). The latter probably represents the most northerly record for both the leatherback and its barnacle hitch-hiker. Elsewhere *S. dermochelys* has a cosmopolitan distribution on leatherbacks from the Atlantic and Pacific Oceans and appears to be restricted to this one turtle species (Hayashi, 2013; Zardus, 2021).

Southward (2008) suggested that *Platylepas hexastylos* might occur on turtles around the British Isles but stated that there were no records from British or Irish waters. In fact, there is a record of this barnacle from a leatherback landed at Dingle, south-west Ireland in July 1978 (O'Riordan, 1979). *P. hexastylos* is flat, cone-shaped, up to 14 mm diameter, and clings to its host by partially embedding its base via downward projecting midribs (Monroe & Limpus, 1979; Zullo, 1979; Zardus, 2021). It also has a cosmopolitan distribution on various turtle species from the Mediterranean Sea and the Atlantic and Pacific Oceans (Hayashi, 2013). However, a sibling species, *P. coriacea*, is now known to occur exclusively on leatherbacks and the Dingle record almost certainly refers to this latter species (Zardus, 2021). In contrast, *P. hexastylos* has been recorded from a loggerhead in the Netherlands along with *C. caretta* (Holthuis, 1952). A summary of all the records of British and Irish turtle barnacles cited here and any additional records from the 'TURTLE' database is provided in Table 2.

Taxonomic confusion in the genus *Stomatolepas*

Among the turtle barnacles, the genus *Stomatolepas* is characterised by bowl- or boat-shaped shells with elaborate sutural ornamentation which helps secure the barnacle within its host's tissue (Epibiont Research Cooperative, 2007; Zardus, 2021). There has been considerable uncertainty regarding the taxonomy within the genus. Five species are listed in the ERC synopsis (2007) but Zardus & Balazs (2007) noted there is confusion with the nomenclature. This was investigated, in part, in a morphological study by Frick *et al.* (2010a) who stated that *Stomatolepas elegans* (Costa, 1838) should be regarded as a valid species and designated a

Turtle	Location	Date	Barnacles (some source nomenclature updated)	Source
Loggerhead (1923/02)	Skye, Scotland	Dec. 1923	*Lepas hilli, Conchoderma virgatum*, *Chelonibia caretta*	Ritchie, 1924a,b
Kemp's Ridley (T1938/05)	Jersey	Dec. 1938	Goose barnacles on shell	Brongersma, 1972
Loggerhead (T1938/09)	Bognor Regis, Sussex, England	Dec. 1938	Goose barnacles attached	Brongersma, 1972
Loggerhead (T1950/02)	Jersey	Nov. 1950	Goose barnacles (turtle upside-down)	Brongersma, 1972
Leatherback (T1959/03	Kilbrannan Sound, Firth of Clyde, Scotland	Aug. 1959	Sessile barnacles	Stephen, 1961
Leatherback (T1967/11)	Crail, Fife, Scotland	Nov. 1967	*Stomatolepas dermochelys*	Smaldon & Lyster, 1976
Loggerhead (T1970/04)	Perranporth, Cornwall, England	Nov. 1970	*Lepas anatifera* on underside	TURTLE Database
Leatherback (T1971/03)	Cork, Ireland	Jul. 1971	*Stomatolepas dermochelys*	Brongersma, 1972; Smaldon & Lyster, 1976; O'Riordan & Holmes, 1978
Leatherback (T1971/05)	Enys Head, The Lizard, Cornwall, England	Jul. 1971	*Stomatolepas dermochelys*	Brongersma, 1972; Smaldon & Lyster, 1976
Leatherback (T1973/04)	Malin Head, Donegal, Ireland	Jul. 1973	*Stomatolepas dermochelys*	O'Riordan & Holmes, 1978
Leatherback (T1975/05)	Stairhaven, Luce Bay, Kirkcudbrightshire, Scotland	Jul. 1975	*Stomatolepas dermochelys*	Smaldon & Lyster, 1976
Leatherback (T1976/03)	Ventry, Kerry, Ireland	Jul. 1976	*Stomatolepas dermochelys*	O'Riordan & Holmes, 1978
Leatherback (T1978/07)	Dingle, Kerry, Ireland	Jul. 1978	*Platylepas coriacea*	O'Riordan, 1979
Leatherback (T1983/08)	Quilty, Clare, Ireland	Jul. 1983	*Conchoderma virgatum*	O'Connor & Bowmer, 1985
Unidentified (T1992/56)	Cork, Ireland	1992	Barnacles on carapace & head	
Leatherback (T1993/17)	Lleyn Peninsula, Gwynedd, Wales	Jul. 1993	*Chelonibia testudinaria*	Rees & Walker, 1993
Leatherback (T1997/03)	St. Anthony Lighthouse, Cornwall, England	Jun. 1997	Back covered in barnacles	TURTLE Database
Loggerhead (T2006/39)	Pembray, Carmarthenshire, Wales	Dec. 2006	*Lepas anatifera*	Penrose & Gander, 2007
Unidentified (T2008/57)	Wexford, Ireland	Jul. 2008	Barnacles on carapace	TURTLE Database
Loggerhead (T2015/27)	Irvine, North Ayrshire, Scotland	Dec. 2015	*Lepas anatifera*	Brownlow *et al*., 2016; Penrose & Gander, 2016
Loggerhead (T2016/01)	Gwithian Beach, Hayle, Cornwall, England	Jan. 2016	*Lepas hillii*	Penrose & Gander, 2017
Leatherback (T2016/02)	St. Cyrus, Aberdeenshire, Scotland	Jan. 2016	*Stomatolepas dermochelys*	Brownlow *et al*., 2017; Penrose & Gander, 2017
Leatherback (T2018/04)	Marazion, Cornwall, England	Aug. 2018	*Stomatolepas dermochelys*	David Fenwick

Table 2. Barnacles reported on marine turtles in the waters around the U.K. and Ireland. TURTLE database numbers are in parenthesis.

neotype specimen to justify this view. They stated that *S. dermochelys*, erected by Monroe & Limpus (1979), was unnecessary and should be considered as a junior synonym of *S. elegans*. They redescribed *S. praegustator*, a species which surprisingly is often found living within the mouth of leatherbacks or loggerheads. This was the type of the genus *Stomatolepas* Pilsbry 2010 which can be loosely translated as "mouth barnacle" with *praegustator* meaning "before eating". This species was considered commensal by Pilsbry (1910) presuming that it shared some of its host's food, but since then has also been found living externally on the neck of leatherbacks or softer parts of the plastron of loggerheads (Frick *et al*., 2010a). A new species, *S. pilsbryi*, was also described by Frick *et al*. (2010a) from the skin of leatherbacks off Gabon, Africa. Hence their *S. elegans* is known from leatherbacks, loggerheads, green turtles, and olive ridleys and it appears that *S. elegans* may occur in sympatry on the same leatherback turtle along with *S. praegustator* or with *S. pilsbryi* with all three species known from Atlantic waters.

Two additional *Stomatolepas* species, *S. transversa* and *S. pulchra*, have been described from turtles in pacific waters (Nilsson-Cantell, 1930; Ren, 1980). *S. transversa* is now also known from the south Atlantic (Young, 1991) and has a characteristic boat-shaped shell (Hayashi, 2012). *S. pulchra* has a similar narrow elliptical shaped shell and Hayashi (2013) argued that *S. pulchra,* should be considered as a junior synonym of *S. transversa*.

The confusion regarding the synonymy of *S. elegans* and *S. dermochelys* persisted in Hayashi (2012), who considered further phylogenetic work is required and, despite a stern rejoinder by Frick (2013), a distinction between *S. elegans* and *S. dermochelys*, mostly based on host preference, continued in Hayashi's checklist of barnacles from turtles and whales (2013). However, a study of epibionts from turtles on the Pacific coast of Mexico by Lazo-Wasem *et al*. (2011) showed a morphological range in *Stomatolepas* specimens which seemed to encompass both *S. elegans* and *S. praegustator.* Subsequently Frick (2013) also hinted that *S. praegustator* could possibly be a junior synonym of *S. elegans* and a genetic analysis by Pinou *et al.* (2013) supported this hypothesis and also suggested that species level complexity for *S. elegans* may be greater than currently recognised. However, *S. praegustator* has not yet been formally synonymised with *S. elegans*, nor has the proposed synonymy of *S. elegans* and *S. dermochelys* been confirmed genetically, thus it is evident that further work is required to elucidate the taxonomy of the *S. elegans* species complex. In the meantime, this paper has followed Monroe & Limpus (1979), and aligned with Hayashi (2013), in anticipation that future genetic studies will eventually resolve the confusion within the genus *Stomatolepas* outlined here.

Although up to five *Stomatolepas* species (*S. elegans, S. dermochelys, S. praegustator, S. transversa,* and *S. pilsbryi*) can potentially be regarded as valid, *S. pulchra* still mistakenly appears as an accepted species on the World Register of Marine Species (WoRMS, https://www.marinespecies.org/). The WoRMS website also incorrectly synonymises *S. praegustator* with *S. elegans* based on an unjustified supposition of Foster (1978). To add to this confusion, the WoRMS website erroneously includes "*Stomatolepas muricata*" as a member of the genus *Stomatolepas* when this species has always been in a different genus by itself, as *Stephanolepas muricata* Fischer, 1886, which is also listed separately on the WoRMS website.

Other barnacles that might occur on turtles in British or Irish waters

Any turtles migrating, or wandering, around the North Atlantic or from the Mediterranean could potentially carry barnacle hitch-hikers to British or Irish seas. It is evident that three lepadomorph goose barnacle species (*L. anatifera, L. hillii* and *C. virgatum*) and four balanomorph turtle barnacle species (*Chelonibia caretta*, *C. testudinaria, Stomatolepas dermochelys* and *Platylepas coriacea*) are now known to have occurred on turtles within the waters of the U.K. or Ireland. It is feasible that other lepadomorphs, such as *L. anserifera* and *L. pectinata*, already known from flotsam in British waters, and from turtles in the Mediterranean Sea, may eventually be found on turtles in British Seas. The rabbit-eared goose barnacle, *Conchoderma auritum*, is known in British, or Irish, waters from ships' hulls (MBA, 1957; Evans, 2000; Anon., 2015; King, 2015) and from whales (O'Connor & Fariñas Franco, 2003) but elsewhere it has also occasionally been recorded from turtles (Monroe & Limpus, 1979; Frick, 2015; Majewska *et al*., 2015).

Other species of balanomorph barnacles are also likely to occur on turtles entering British waters. Leatherbacks, which are the most regular turtle visitors, are known as vectors for *C. testudinaria, S. dermochelys* and *P. coriacea*, and these barnacles may be viewed as genuine members of the British barnacle fauna, albeit as summer migrants. However, other barnacle species on leatherbacks may have been overlooked as small barnacles on such big turtles, with mottled colouration, can easily be missed, even on stranded specimens. *Stomatolepas praegustator* which usually inhabits the mouth or gullet of leatherbacks, and other turtles, may also occur but would require careful examination to find specimens (Pilsbry, 1910; Frick *et al*., 2010a). The "*S. elegans*" found on the fins and shoulder of the leatherback in the Netherlands by Holthuis (1969) was regarded as referable to *S. praegustator* by Monroe & Limpus (1979) although, as discussed above, the status of this species warrants further study. The mouth of the St. Cyrus leatherback discussed here was examined. It showed the unusual recurved fleshy spines which hold its slippery prey but no barnacles were observed (Fig. 12). *Stomatolepas pilsbryi,* known to date only from leatherbacks off Gabon, may also have been overlooked and could perhaps reach British waters (Frick *et al*., 2010a). Leatherbacks from Nova Scotia, eastern Canada, which could easily travel onwards to

British waters, have been found to host *L. anatifera, C. auritum, C. virgatum, S. dermochelys* and *P. coriacea* (Frick, 2015).

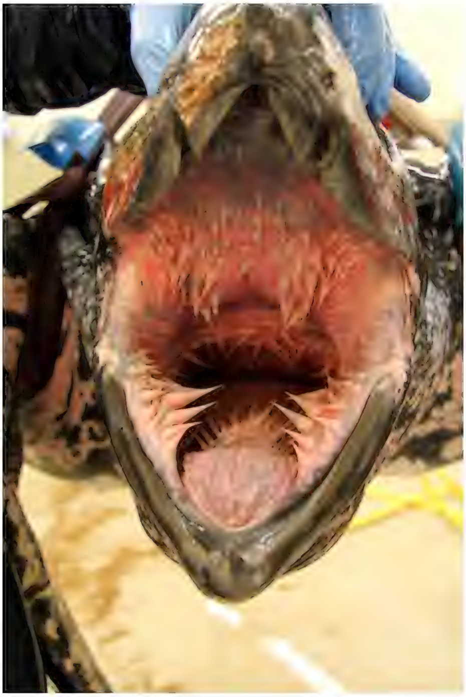

Fig. 12. Mouth of leatherback turtle (*Dermochelys coriacea*) from St. Cyrus, Scotland, January 2016, showing recurved fleshy spines. (Photo: SMASS)

Turtles and their epibionts from the Mediterranean Sea are relatively well studied (Fuller *et al.*, 2010; Domenèch *et al.,* 2015; Casale *et al.*, 2018; Ten *et al.*, 2019) and their barnacle fauna may indicate species likely to arrive on British shores as vagrants. Seven balanomorph barnacles are cited by Hayashi (2013) as occurring on turtles from the Mediterranean. Some of these have yet to be found from British or Irish waters: *Chelonibia patula* was recorded from loggerheads in Greece (Kitsos *et al.*, 2003, 2005), and is also found on crabs and bivalves in the Mediterranean (Bakir *et al.*, 2010; Beşir & Çınar, 2012). However, Cheang *et al.* (2013) have since shown that *C. testudinaria* and *C. patula* are conspecific. Both *Platylepas hexastylos* and *P. coriacea* were recorded from loggerheads in Malta (Gramentz, 1988), though the latter is likely to be a misidentification. *P. hexastylos* has also been found on Aegean loggerheads (Kitsos *et al.*, 2005), and has already reached the Netherlands on a loggerhead (Holthuis, 1952). There is a single old record of *P. decorata* from Corsica from an unknown turtle host (Gray, 1825), this barnacle being known elsewhere from loggerhead, green, and Kemp's ridley turtles. Small species, such as *Stephanolepas muricata*, which penetrate deep into the skin of turtles, could easily be overlooked (Frick *et al.*, 2011). This species, originally described from Vietnam (Fischer, 1886), was cited as occurring only from Pacific waters and from Florida by Hayashi (2013). In fact it was discovered in the western Mediterranean in 2007, infesting loggerheads (Badillo-Amador, 2007), and since then has also been found on loggerheads in the central Mediterranean (Casale *et al.*, 2012; Karaa *et al.*, 2012).

It is feasible that other balanomorph turtle barnacles from the western North Atlantic may, on rare occasions, appear in British waters. These could include *Cylindrolepas darwiniana* known from loggerheads and hawksbills (Frick & Zardus, 2010) or *Calyptolepas bjorndalae* from loggerheads and green turtles (Frick *et al.*, 2010b). Surprisingly this latter genus and species does not appear on the WoRMS website. *Chelonibia manati* is also known from loggerheads, green turtles, and also manatees in the western North Atlantic (Pilsbry, 1916; Wells, 1966) but recent genetic studies (Zardus *et al.*, 2014) have shown *C. manati* and *C. patula* to be host morphotypes which should both be synonymised with *C. testudinaria*.

A further 19 species of non-coronuloid acorn barnacles are cited in the Epibiont Research Cooperative synopsis (2007) as very occasionally occurring on turtles and an additional non-obligate species has since been found on Japanese loggerheads (Hayashi, 2016). Of these non-obligate turtle barnacles, five (*Amphibalanus amphitrite, A. eburneus, Balanus trigonus, Perforatus perforatus* and *Pachylasma giganteum*) have been found on Mediterranean loggerheads (Karaa *et al.*, 2012). Both *A. amphitrite* and *P. perforatus* already occur on shores of southern England (Southward, 2008). The only non-chelonophilic barnacles found from a turtle close to British waters were small specimens of the Australian barnacle *Austrominius modestus*, found on a green turtle washed ashore in the Netherlands in 1952 (Brongersma, 1972). However, this introduced barnacle species was already widespread on the shores of the English Channel at that time and is likely to have infected the turtle on its arrival there. Although these exotic barnacles are more likely to arrive on flotsam or ships' hulls, some could potentially appear on turtles arriving in British waters. Even gulls (with plastic leg rings) have now been shown to act as occasional vectors for non-indigenous barnacles to European waters (Tøttrup *et al.*, 2010).

Effects of barnacles on turtles and removal strategies

The epibiont communities on sea turtles are discussed at length by Casale *et al.* (2012), Frick & Pfaller (2013) and Robinson & Pfaller (2022). These communities can include a variety of different organisms and may change their composition with the long-distance migrations of their turtle hosts. Healthy turtles indulge in cleaning associations or self-grooming activities to control epibionts. However, *Lepas* goose barnacles, in particular, are known to grow quite rapidly (Evans, 1958; MacIntyre, 1966; Eckert & Eckert, 1987; Mesaglio *et al.*, 2021). They typically reach up to 15 cm stalk length with a capitulum of 3-4 cm but in extreme examples may achieve a stalk up to 80 cm in length and a capitulum of 7 cm in length (De Wolf, 2008; Jensen, 2010). Hence, heavy infestation by goose barnacles can seriously affect the turtle's ability to swim and forage (Casale *et al*., 2012), as is highlighted by the examples herein.

Among the coronuloid turtle barnacles, different modes of attachment – cementing, clinging, embedding, boring – result in characteristic modified shell morphologies which make these turtle specialists increasingly difficult for their hosts to remove. The embedded *S. dermochelys* highlighted here are unlikely to be dislodged by grooming activities. However, the embedded chelonophilic barnacles are usually less problematic to the turtles although some of the boring species can cause harm to their hosts. Dense aggregations of acorn barnacles may accumulate on sick or moribund turtles to their detriment (Casale *et al*., 2012; Zardus, 2021). Such turtles, colloquially known as "Barnacle Bills", are generally considered to be suffering from debilitated turtle syndrome (Norton *et al*., 2008; Sloan *et al*. 2014).

Turtles can minimise the settlement of epifauna by sloughing skin (Frick *et al.,* 2011; Frick, 2015) or attending grooming stations where cleaning fish remove epibionts (Sazima *et al*., 2010). Columbus crabs which often live on turtles may help to remove settling larvae (Davenport, 1994). Groupers have also been observed removing goose barnacles and predating accompanying pilot fish (Hackradt *et al*., 2013). Turtles can also remove some barnacles by rubbing on rocks on the sea-bed or in rock crevices (Heithaus *et al*., 2002; Frick & McFall, 2007). Turtles do eat epibionts, including goose barnacles from floating objects (Brongersma, 1972; van Nierop & den Hartog, 1984), and recent studies with turtle-cams attached to loggerheads in Cape Verde Islands have shown they may graze epibionts from fellow turtles (BBC, 2021).

OTHER EXOTIC FAUNA ACCOMPANYING TURTLES

It is worth noting that migrating leatherbacks bring more than just barnacles to British waters. They are sometimes accompanied by pilot fish (*Naucrates ductor*) or remora fish (*Echeneis naucrates*). Several records were cited by Brongersma (1972) of both of these fish with leatherbacks in French waters, one record of pilot fish with a leatherback from Dorset and two records of pilot fish with leatherbacks from Norway. Since then pilot fish have been reported from leatherbacks entangled off Wester Skeld, Shetland, in 1973, and off Skerray, Sutherland, in 1989 (Langton, 1996). In Irish waters there have been at least 30 records of pilot fish with leatherbacks, with up to 80 fish accompanying one turtle, and ten records of remoras with leatherbacks (King & Berrow, 2009). The "most northerly" leatherback (cited above) with *S. dermochelys* barnacles and captured above the Arctic circle at Finnmark, Norway, in 1997, also had accompanying pilot fish (Carriol & Vader, 2002).

Columbus crabs (*Planes minutus*) are also known as hitchhikers on marine turtles, especially loggerheads (Davenport, 1994; Dellinger *et al*., 1997), and have been recovered from a loggerhead stranded in Ireland (Doyle *et al*., 2013). Two other unusual crustaceans, the copepod *Balaenophilus manatorum,* and the amphipod *Podocerus chelonophilus*, are listed as obligate epibionts of loggerheads in the Mediterranean (Domenèch *et al*., 2015) and could be found on these turtles in British or Irish waters. Similarly, the turtle leech*, Ozobranchus margoi*, is also known from Mediterranean loggerheads (Insacco *et al*., 2001; Badillo-Amador, 2007; Domenèch *et al*., 2015) and could be found on turtles that arrive in Scottish waters. This unusual ecto-parasitic leech is 10-15 mm in length with five pairs of external arborescent gills and dozens may attach to turtles, especially around the cloacal region (Davies, 1978; Karaa *et al*., 2019).

CONCLUDING REMARKS

Although marine turtles such as the leatherback are now known to be regular migrants to British waters, few people get to see them and sightings, strandings or entanglements of these leviathan beasts can be a newsworthy event (BBC, 2014; Barbour, 2014). Associated turtle barnacles are rarely recorded in British waters but their occurrence presents an insight into the fascinating stories behind the evolution and ecology of these enigmatic creatures. Further examination of turtles entering British waters should help shed light on turtle epibionts and perhaps reveal species new to British seas. For the marine taxonomist a rare barnacle brought to British shores on a turtle riding a trans-oceanic current generates a similar level of excitement as a rare bird arriving with unusual trans-oceanic winds.

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Scientific study in the Loch Lomond and Trossachs area, Scotland

C.E. Adams[1*], R. Smith[1], W. El Bestawy[1], J.R. Rodger[1], H.M. Honkanen[1], P.S. Maitland[2] & S. White[3]

[1] Scottish Centre for Ecology and the Natural Environment, Rowardennan G63 OAW
[2] Nether Sunnyside, Haddington EH41 4NR
[3] Institute of Biodiversity, Animal Health and Comparative Medicine, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ

*E-mail: colin.adams@glasgow.ac.uk

ABSTRACT

The natural environment of the Loch Lomondside area, Scotland is exceptionally well-studied. Here we describe a project to catalogue publications that describe these studies, and to form a living database of references. We recorded 1,436 references from the mainstream scientific literature and reports from the "grey literature". The taxonomic groups and habitats studied were highly skewed. Faunal studies were considerably commoner than those of flora; studies on vertebrate species were commoner than those on invertebrate species; fish and birds were more commonly studied than other vertebrate groups. Reports of studies on terrestrial ecosystems were more frequent than those on aquatic systems. Amongst freshwater species, some groups were very poorly represented (e.g. Rotifera, Hydracarina, Diptera, Nematoda, Microturbellaria and Tardigrada). Many studies have made very significant contributions to understanding the mechanisms that operate in the natural environment. The underlying reasons for the important contributions that the Loch Lomondside area has made to natural science are discussed.

INTRODUCTION

As a platform for naturalists and scientists to investigate the patterns of the natural world and the processes that drive it, Loch Lomond, Scotland punches well above its weight. A search of the Web of Science databases of published literature yields 474 publications with "Lomond" in the title, abstract or keywords from the years 1864 to 2021 (excluding those concerning the glacial readvance known as the Loch Lomond stadial). This contrasts with 425 for Loch Ness (the number for which decreases to 305 if the, arguably non-scientific, publications relating to the Loch Ness monster are removed) and 279 for Loch Leven. In the wider U.K., this publication rate for studies on freshwaters is exceeded only by Lake Windermere (494 publications), where since 1931 the Freshwater Biological Association (FBA) has been based on its shores. For many years, the FBA was the major force driving high quality fundamental science of internationally high standing on freshwater systems; later the freshwater research based there was conducted by government science institutes, initially through the Institute of Freshwater Ecology and latterly by the Centre for Ecology and Hydrology, until 2004 when this moved on to the Lancaster University campus.

Thus, Loch Lomond can reasonably lay claim to be the most studied lake ecosystem in Scotland and the second most studied in the U.K. Here, we describe the outcome of a project to draw together information on studies that underpin that claim and to make this information available to scientists, naturalists and the wider public.

METHODS

With funding from the Glasgow Natural History Society through the Blodwen Lloyd Binns grant scheme, we compiled a bibliography of published scientific literature on Loch Lomond and its wider catchment. The current bibliography was founded on work begun by one of the authors here (PSM) which provided references in the field of freshwater biology around two decades ago (Maitland *et al.,* 2001). Recognising that the value of such work may be enhanced by extending the geographic range to include the Trossachs area, we have included any published studies that were wholly, or partly, conducted in the geographic area that is very approximately bounded by the Loch Lomond and the Trossachs National Park, an area covering 1,865 km^2 (Loch Lomond & The Trossachs National Park, 2021). In addition, we considerably extend the scope of topics to cover terrestrial and in some cases marine ecosystems.

Included in the database is literature published in peer-reviewed, national and international scientific journals, as well as less accessible and more difficult to find publications in the "grey" literature. This comprises government and non-governmental agency reports, including both material subject to peer-review and not peer-reviewed. We also include post-graduate theses, most of which are now either in the public domain or accessible through the academic institutions to which they were submitted. Although they have the potential to make very insightful contributions to our understanding of the natural world, we do not include studies conducted by undergraduates as Honours projects. This is in part because these are examinable documents usually subject to embargo but also because there is (as yet) no way to consistently capture information on where, and when, such studies are conducted.

In addition, we were also selective in the literature topics that we covered. Our aim was to capture references describing scientific studies on the natural world conducted in the defined study area. Thus, we covered obvious broad topics such as ecology, chemistry and geology. We also included topics such as physics and parasite and disease ecology where this pertained to the natural environment. References relating to geographic topics such as land use, forestry, fisheries, hydrology, meteorology, planning, land use and tourism, were included where it was clear that the study topic was relevant to the natural environment.

We did not include the vast literature on topics that did not contribute to a scientific understanding of the mechanisms in the natural world. Despite their ability to communicate an emotional perception of the natural world, we did not include references to poetry, song, music, novels or other creative writing. Also excluded were works of non-fiction focused on hobbies or pastimes, travelogues, landscape descriptions and references to historical studies (cultural, social or political), with the exception of a few cases where they provided insights into the processes in natural world.

We populated our database beginning with the references in the original database from 2001 (Maitland *et al.*, 2001), which comprises 640 references, and then added to this by searching Web of Science, Google Scholar and the Google search engine to search more widely. The process was completed with the final electronic searches undertaken in summer of 2021. We manually scoured hard copies of smaller national natural history and environmental journals which are not included in the Science Citation Index or Web of Science. For a number of key publications, we searched their citations lists to add to the database.

RESULTS

General comments on the literature

In total, we have recorded 1,436 references covering a wide range of topics pertaining to the natural world in Loch Lomondside and the Trossachs. A breakdown of references by subject topic, habitat and taxonomic group is provided (Table 1). It is informative to examine how much attention has been given to topics by previous studies, not simply to identify what has been covered but, more importantly, to identify the areas that are less well known.

The coverage of studies represented in the literature was markedly skewed across taxonomic groups, topics and habitats. References relating to study of the aquatic environment dominated those of studies on terrestrial systems by a factor of three. Unsurprisingly, given the study selection criteria, studies that were primarily ecological in nature vastly outnumbered those that were geographical or from the social sciences. There were four times as many studies looking at fauna of the region than those on the flora. Of all animal studies, 78% looked at vertebrates compared with 22% on invertebrates. Amongst the vertebrate studies, fish and bird studies dominated (88%) compared with other groups. Where it was possible to determine the context for the study, applied conservation was the commonest reason (65%) given for the background to the study.

Important amongst the assembled references are six major monographs on aspects of the natural world in the Loch Lomond and Trossachs area. Two of these are by a single author: Maitland (1966) is a highly detailed account of the ecology of the Endrick Water (which drains the south east of the Lomond catchment) resulting from an intensive three-year study of the invertebrate and vertebrate fauna there; whereas Mitchell (2001) is a highly authoritative summary of knowledge of the natural history, diversity and land use changes of the area derived from the insight accrued from decades of work by the author.

The remaining four are multi-author monographs. Tippett (1974) is a comprehensive description of the natural history of the Loch Lomondside area, covering a range of topics including geology, terrestrial and freshwater flora and fauna, archaeology, local history, and land and water use. Murphy *et al.* (1994) comprises a collection of papers emanating from a symposium on Loch Lomond ecology held in 1992 to celebrate 25 years of research at the University of Glasgow's field station at Rowardennan on east Loch Lomondside. The topics in these 19 papers by 29 authors range from loch eutrophication and sediment chemistry through plankton, invertebrate, fish and vegetation ecology, to geology and hydrology. Slack (1957) is a selected summary of research work conducted at the University of Glasgow's field station at Rossdhu on west Loch Lomondside, between 1946 and 1957 (see Maitland & Hamilton, 1994). It includes an eclectic mix of chapters on the topography, physical and chemical nature of Loch Lomond and its aquatic fauna, the invertebrate communities of a well-studied offshore reef, gastropod ecology, biting midges, the basic biology of the powan (*Coregonus lavaretus*), and the parasites of fish. Downie & Weddle (2005) consists of the proceedings of a 2004 conference on the natural history of Loch Lomond and the Trossachs. The nine articles cover a wide range of topics from flora and fauna to practical wildlife management.

Several authors have made very considerable contributions to the scientific literature of the area. Notable amongst these is John Mitchell who for 27 years was in charge of the Endrick Mouth National Nature Reserve and who contributed 126 publications to the database, considerably more than any other author.

Important science that has resulted from studies in the Loch Lomond area

Many of the studies captured in the bibliography described here have had an impact on our understanding of the mechanisms that operate in the natural world well beyond the study area. A comprehensive analysis of the enormous range and depth of science that has emanated from this area is beyond the scope of this current paper but to provide a flavour of the range of such work we describe a few of these here.

Study topic	Habitat Type	Plant*	Invertebrate	Vertebrate	General Field
Ecology (921)	Aquatic (876)	Plants (182)	Insect (60)	Fish (271)	Conservation (483)
Geography (247)	Terrestrial (279)		Mollusc (18)	Bird (244)	Management (230)
Social Science (154)			Crustacean (9)	Mammal (51)	Pure Science (35)
Geology (89)			Other (81)	Reptile (9)	
Chemistry (69)				Amphibian (6)	
Physics (27)				Other (7)	
Biology (11)					

Table 1. The subject, habitat type and taxonomic breakdown of the 1,436 references to scientific publications on the natural world from the Loch Lomond and Trossachs area included in the database to date. *"Plant" here includes vascular and non-vascular plants.

Loch Lomond was one of the first lakes in the world to have the pattern of temperature change with depth described (in 1812). Although commonplace today using electronic thermometers, in 1812 (Leslie, 1838) a complex registering thermometer was required to take a temperature measurement at depth without the reading being altered by the temperature of the water above as it was retrieved to the boat.

Bathymetric surveys of Loch Lomond and Loch Awe in 1861 by the Royal Navy, under the direction of Captain H.C. Otter, were the first systematic bathymetric surveys of Scottish freshwater lochs. This work was conducted under the auspices of improving navigation for shipping (Murray & Pullar, 1900). It was a further 40 years before surveying of a further 562 lochs around Scotland began, arguably laying the foundation for the most comprehensive freshwater study ever undertaken in the U.K. (Murray & Pullar, 1910).

The detailed work of Maitland (1966) on invertebrate community succession along a stream channel continuum conducted in the Endrick Water provided a major strand of the empirical evidence for the articulation of the biological elements of the River Continuum Concept, a fundamental concept in freshwater science, some 25 years later (Vannote *et al.*, 1980).

The first report of a seiche, a periodic short duration oscillation of the water in a lake, resulting from an earthquake, was described from Loch Lomond in the aftermath of the Lisbon earthquake on the 1st November 1755 (Loch Lomond was *ca.* 2,000 km from the epicentre of the earthquake) (Anonymous, 1755). The period of oscillation was around 10 minutes and the amplitude of water height change over this time about 75 cm (Chrystal, 1910). This observation was made 135 years before the term seiche was first coined by the famous Swiss hydrologist Francois-Alphose Forel (Forel, 1886).

In more recent times Pollock *et al.* (2017) showed a very strong effect of urbanisation on blue tit (*Cyanistes caeruleus*) breeding success, which was five times lower in urban areas compared with Loch Lomondside, and linked this to the quality of available food. Hume *et al.* (2018) used molecular genetics techniques to disentangle the evolutionary origins of a rare and protected form of lamprey found in the Lomond catchment and only a few other places in the world. A highly protected fish - the powan *Coregonus lavaretus* - from Loch Lomond and Loch Eck formed an important part of a study to address questions about intra-specific structuring, the very first signs of the emergence of new biodiversity. Crotti *et al.* (2020) sampled powan from Lochs Lomond and Eck and were able to describe complex patterns of genetic structuring across the species. They were able to show how novel diversity has emerged and they put this into the context of the conservation needs for this species.

James *et al.* (2011) published an important study on the role of passerine birds as hosts of ticks and the transmission of *Borrelia burgdorferi*, the agent of Lyme disease. The vast majority of previous research having been on the role of mammals in the transmission of this disease, there is very little in the scientific literature on the importance the role birds may also play in Lyme disease transmission. Another important recent publication is that of Jerem *et al.* (2015) which describes a newly developed non-invasive technique employing thermal imaging technology for measuring stress in wild birds. Whilst the majority of the vertebrate research at Loch Lomond has focused on fish and birds, Muir *et al.* (2014) uses molecular techniques to study adaptation to altitude in the common frog (*Rana temporaria).*

On a less serious note, it is fascinating to scroll through some of the short notes dating back to the 1850s to find records of exotic organisms such as Bonaparte's gull (*Chroicocephalus philadelphia*) (Leith, 1851), loggerhead turtle (*Caretta caretta*) (Gray & Smee, 1861), ruby-crowned kinglet/wren (*Corthylio calendula*) (Lumsden, 1904; Mitchell, 1983,1991) although the wild provenance of this bird has not been confirmed (Forrester *et al.* 2007), and pomarine skua (*Stercorarius pomarinus)* (Kirk, 1903).

Why is the Loch Lomond area so well studied?

It is clear that the terrestrial and aquatic habitats of the study area defined here have received disproportionately high research attention compared with many other places. There are a number of reasons why this might be so.

The Loch Lomond area is clearly an area of high biodiversity. Around 540 species of flowering plants and ferns comprising 25% of all U.K. species (Idle, 1974) and 31 species (49%) of the 64 native and naturalised mammals (excluding vagrants, marine species and island endemics) (Mitchell, 1974; Mammal Society, 2020) are found on Loch Lomondside. In freshwater, Loch Lomond supports the highest diversity of native fish species of any Scottish loch. This comprises 65% (17 species) of the native freshwater fish fauna of Scotland (Maitland *et al*., 2000). Although some groups of freshwater invertebrates have been recorded only poorly or not at all (particularly Rotifera, Hydracarina, Diptera, Nematoda, Microturbellaria, Tardigrada), 450 freshwater species of the 3,500 known from the U.K. have been recorded there (Adams *et al.,* 1990). All of this points towards a highly diverse flora and fauna of this area.

There is no doubt that this high diversity is, in part, a result of the area being bisected by the Highland Boundary Fault. This major fault line marks the separation of the distinct geologies of the Scottish Highlands from that of the Central Lowlands. Loch Lomond is the only major freshwater body straddling this fault. As a result, Loch Lomond and its catchment are partly in the low-lying, nutrient-rich, central lowlands and partly in the nutrient-poor highlands. This feature creates very considerable habitat diversity in the loch itself but also within the wider catchment, which certainly contributes to the species richness of the area. Thus Loch Lomondside is where the southern edge of more northerly species coincide with the northerly edge of more southerly species (Idle, 1974; Maitland *et al*., 2000)

There is also a considerable number of species recorded from the study area that are relatively rare, in a national or international context. Table 2 lists those for which there is some published information. Twenty-four species are listed, along with some information explaining their inclusion here. Notable amongst these is the Lomond dock (*Rumex aquaticus)*, which is known only from the study area, and an abyssal oligochaete, the Lomond worm (*Arcteonais lomondi)* (Martin, 1907), originally described from samples from Loch Lomond and with a very limited distribution in the U.K. It is a little unclear whether the presence of these rare species has stimulated research interest in the Loch Lomond area or if we know of the existence of these species only because of the focus on research there; a combination of both effects is the most likely.

One factor that has certainly stimulated scientific investigation of the area has been the establishment of a permanent research base there. The University of Glasgow has operated a field research station on Loch Lomond continuously since 1946. Initially on the west of Loch Lomond at Rossdhu, after 1964 this moved to purpose-built facilities on east Loch Lomondside at Rowardennan (Maitland & Hamilton, 1994). Used as a base for field research, academic and research staff and research students from the University of Glasgow and their national and international collaborators have made a considerable contribution to understanding the mechanisms driving ecological processes using local study systems. Of the references listed in the bibliography detailed here, 399 have resulted directly from work conducted at the Scottish Centre for Ecology and the Natural Environment and its predecessor, the University Field Station.

The high diversity and presence of rare species have resulted in a number of designations which are related to the conservation of nature. There are 67 formally designated sites. One important site, the area around the mouth of the Endrick Water, where it discharges into the south-east corner of Loch Lomond, carries eight designations for its special features. The area is a Site of Special Scientific Interest, a Special Area for Conservation, a Special Protection Area, a Ramsar site, a National Scenic Area, a National Nature Reserve, in a National Park and an RSPB Nature Reserve.

The bibliography

The bibliography of references on the study area described above is undoubtedly incomplete. It is impossible to locate all relevant references, especially those in the more difficult grey literature. The law of diminishing returns has required us to bring active searching for additional references to a close. In addition, new studies relevant to the area are emerging monthly. We thus regard the bibliography as a living entity that can and should be added to, amended and expanded. The bibliography is available in a format that can be utilised by those who use reference management software (Bibtex). In addition, we also make the bibliography entries available in the near-universal pdf format, readers for which are freely available and these have search functions to aid in finding references of interest to the user.

These versions are available at: https://drive.google.com/drive/folders/1NHYtQQY8rccVYfaqUcF8tmVLBD_4g2zp?usp=sharing
The bibliography is inevitably out of date, even as you read this; new science and knowledge are being generated constantly. It is the authors' intention to update the bibliography periodically. If you find appropriate references that can be added to this database, please do send them to: lomond.biblio@gmail.com.

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Scientific Name	Common Name	Description
Arcteonais lomondi	**Lomond worm**	Found in the profundal mud, this worm was a species new to science discovered in Loch Lomond, hence the specific name "*lomondi*". Later discovered also in Loch Morar, this species occurs nowhere else in Britain (Maitland *et al*., 2001).
Antrobathynella natans	**subterranean (interstitial) crustacean**	A crustacean found living only in the interstitial spaces in groundwater, this species is only recorded in Scotland in the gravel of the Altquhur burn, a tributary of the Endrick Water (Maitland, 1962). Originally identified as *Bathynella natans*, the species has been moved to the genus *Antrobathynella* (Serban 1973). A re-examination of the original specimens lodged in the Natural History Museum by Proudlove *et al.* (2003), suggest that they may be *Antrobathynella stammeri*. However, this identification remains uncertain. The habitat in which these specimens were found is highly valued as a building material, and thus the species is at risk from gravel excavation and extraction (Maitland, 1962). Two subsequent attempts to find the species at the original site in the last decade have failed (J. Dodd, pers. comm.)
Bithynia leachii	**gastropod mollusc**	This species is a stenotopic freshwater snail restricted to still, high quality waterbodies (Global Biodiversity Information Facility, 2021). Its presence in Loch Lomond is unexpected given its few known localities in Scotland and it is a suspected introduction from southern lakes (Mitchell, 2001).
Pisidium conventus	**bivalve mollusc**	*P. conventus* is a small bivalve mollusc occurring exclusively in the deepest waters of Loch Lomond - the "Tarbet Deep" (Hunter & Slack, 1958). The species is an excellent example of an Arctic relict species found primarily in the profundal areas at depths of 190 m (Maitland & Adams, 2005).
Cordulia aenea	**downy emerald**	*C. aenea* exists in only three scattered populations within Scotland including Loch Lomond and the Dubh Lochan (NBN Atlas, 2021a).
Somatochlora arctica	**northern emerald**	This uncommon dragonfly is confined to scattered populations in north-west Scotland and Ireland, although commoner on the European continent (NBN Atlas, 2021b). Its rarity is partially a consequence of lacking suitable habitat and specific breeding conditions - oligotrophic pools, particularly where sphagnum is present and in close proximity to trees with a lack of open spaces (British Dragonfly Society, 2021).
Lampert fluviatilis	**lake-dwelling parasitic river lamprey**	*L. fluviatilis*, unlike other populations of river lamprey in Scotland, a Loch Lomond population remains in freshwater throughout its entire lifecycle, feeding parasitically on freshwater fish (mostly powan) rather than migrating to sea. This rare life history form is a feature of interest in the Endrick Water SAC designation (NatureScot, 2018).
Coregonus lavaretus	**powan**	The powan may be Scotland's rarest freshwater fish and is an assumed glacial relict species. It is endemic to only two lochs in Scotland, Lomond and Eck, but exists as conservation refuge populations in other water bodies. Although populations are relatively healthy, in recent years the threat of ova predation from the invasive non-native *Gymnocephalus cernuus* in Loch

		Lomond and habitat degradation, have made it a priority species for the U.K. Biodiversity Action plan and it is protected under the Wildlife and Countryside Act 1981 (Adams & Tippett, 1991; Lyle *et al*., 2016).
Salvelinus alpinus	**polymorphic Arctic charr**	*S. alpinus* is another species that invaded freshwater as the last ice age came to an end. Although not found in Loch Lomond itself, this species is recorded throughout the study area (NatureScot, 2021) and is important as a study species to investigate evolutionary questions and its extreme variation is of high conservation interest (Maitland & Adams, 2005).
Rumex aquaticus	**Lomond dock/ Scottish dock**	*R. aquaticus* is a perennial plant endemic only to Loch Lomondside. Preferring periodically inundated low-lying ground, it forms large colonies, particularly around Balmaha (Maitland *et al*., 2001). Although not discovered until 1935, the species has medicinal properties (Grieve, 1984).
Anser albifrons	**Greenland white-fronted goose**	*A. albifrons* began wintering in Loch Lomond in the 1960s, following migration from summer breeding in Greenland (Mitchell, 1994). On the RSPB red-list, the flock of 200 birds that visit the Endrick SSSI annually account for 1% of the total population and are thus of high conservation value (NatureScot, 2018).
Collema dichotomum	**river jelly lichen**	*C. dichotomum* is a cyanobacteria-containing jelly lichen known only in eleven 10 km squares within the U.K. (NBN Atlas, 2021c). This lichen is classified as vulnerable and protected under the Wildlife and Countryside act (1981). It is sensitive to eutrophication and is in decline. Threats include replacement by algal species, pollution and water abstraction for hydroelectric schemes (Air Pollution Information System, 2011; NBN Atlas, 2021c). Its continuing presence on the River Endrick reflects the high ecological status of its water and lack of anthropogenic modification.
Carex elongata	**elongated sedge**	*C. elongata* is sparsely distributed throughout Britain and thought lost to Scotland until rediscovered on Loch Lomondside in 1967; this is now one of only four sites in the country (Mitchell, 2001). The perennial herb is an indicator of high-quality habitats. In the case of Loch Lomond this is ancient woodland (Botanical Society of Britain & Ireland, 2021).
Pandion haliaetus	**osprey**	*P. haliaetus* was lost as a breeding species in 1829 due to persecution. However, in 1990 it returned to Loch Lomond establishing the first breeding pair in over 150 years at the mouth of the river Endrick (Mitchell, 2001), with the species now widespread across Scotland (Forrester *et al.* 2007).
Phylloscopus sibilatrix	**wood warbler**	A summer visitor from sub-Saharan Africa, *P. sibilatrix* is associated with closed canopy oak-woods such as those found around Loch Lomond. *P. sibilatrix* is found locally across Scotland with a large population present around Loch Lomond (Bibby, 1989, Forrester *et al.* 2007) and increasing numbers of males singing in spring 2020 and 2021 (S. White, pers. obs.). This species, along with other oak-wood specialists such as common redstart *Phoenicurus phoenicurus*, pied flycatcher *Ficedula hypoleuca* and tree pipit *Anthus trivialis,* are all present around the loch in nationally significant numbers.
Poecile montana	**willow tit**	*P. montana* is on the U.K. Red List with a limited distribution in Scotland, with the species declining across its British range (Forrester *et al.* 2007). The only large Scottish population is in Dumfries and Galloway with it being extinct from south Lanarkshire since 2010, and just a few pairs remain in southern Ayrshire. However, surveys in 2016 on the islands in Loch Lomond and on the eastern side of the loch showed evidence of a small population (A. Wojciechowska & S. White, pers. comm.), which would represent the most northerly and isolated birds present in Scotland.

Sitta europaea	**wood nuthatch**	*S. europaea* is a recent entry on the Scottish species list, only breeding in the Borders for the first time in 1989, with the species now widespread and common across southern Scotland (Forrester *et al.* 2007). It first appeared in the environment of SCENE around 2016 (S. White, pers. obs.). The birds are now common around the loch and are breeding in the area.
Physcomitrium sphaericum	**dwarf bladder moss**	*P. sphaericum* is a small moss characterised by broad, pointed leaves found in only nine sites in the U.K., and listed rare throughout the rest of Europe (NatureScot, 2018). It is found on the edges of fluctuating ponds, such as Ward's Pond on Loch Lomond, where its small stature at 2-3mm makes it difficult to identify, often going years without a confirmed sighting (Mitchell, 2001).
Elatine hydropiper	**eight-stamened waterwort**	Lost to England in 1944, the species appeared in Scotland in 1968, and has since been discovered in multiple sites, including two on Loch Lomond (Idle *et al.*, 1970). It is generally intolerant of competition and occupies periodically inundated sandbars and mudflats where competition is low, allowing it to solely colonise an area. The wave action and regular water level fluctuation of Loch Lomond is key in maintaining the bare sand and mud habitat of the species, in part explaining its scarce occurrence. The plant is only visible when exposed in periods of low rainfall; this can be as little as 22 days per year (Idle *et al.*, 1970).
Elatine hexandra	**six-stamened waterwort**	Similar to *E. hydropiper*, *E. hexandra* thrives in areas subject to water level fluctuations as it is also intolerant of competition, with the exception of other annual species. In part, thriving in the habitat is due to it being unsuitable for larger rhizomatose perennial plants that are unable to establish on the destabilised soil, and due to its tolerance of harsh winter conditions. Although *E. hexandra* has been recorded historically throughout the Lomond catchment (in the 1960s), it is now limited to the edges of the Kilmannan reservoir where the rhythmic change in water level mimics favourable conditions (Idle *et al.*, 1970). It is regarded as nationally scarce (Online Atlas of the British and Irish Flora, 2021).
Placynthium pannariellum ***Porocyphus kenmorensis*** ***Dermatocarpon meiophyllizum***	**rare lacustrine lichens**	These specialised aquatic lichens have evolved to inhabit the low competition water-line habitats of large lochs in Scotland. Their hostile environment, combined with sporadic appearance, creates difficulties in studying them which may have resulted in under-recording, making Loch Lomond a nationally important site. Presently Scotland remains the stronghold of the species throughout the U.K. and the majority of its distribution is in the Lomond and Trossachs area (British Lichen Society, 2021). Their already, challenging environment is under increasing threat from hydropower development schemes causing rapid water level fluctuations that threaten to wipe out lichen communities.
Pilularia globulifera	**pillwort**	*P. globulifera* can be found in many scattered sites throughout Britain, including the study area included in this paper, but is considered internationally threatened and has shown a decline in range across all of Europe. It inhabits ponds and seasonally fluctuating water bodies, typically on their margins, and often where livestock graze. Drainage schemes and water pollution, notably fertilisers, encourage the growth of coarse plants that outcompete *P. globulifera* causing their decline (Mitchell, 2001).

Table 2. Some species of importance in the national or international context, that are to be found in the study area.

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SUPPLEMENT (Part 3): ON THE WILD SIDE REVISITED: 200 YEARS OF WILDLIFE IN THE GLASGOW BOTANIC GARDENS

The arachnids of Glasgow Botanic Gardens

C. Cathrine[1*], K. Godsman[1], J. Ahmed[2] & N. Currie[1]

[1]Caledonian Conservation Ltd., Office 2 and 3, Craigarnhall, Bridge of Allan, Stirling FK9 4NG
[2]Jai Gopi Krishna CHSL, 'A' Wing, Flat No. 102,1, Patil Wadi, Govandi East, Mumbai, Maharashtra 400088, India

*E-mail: chris.cathrine@caledonianconservation.co.uk

ABSTRACT

This paper provides an overview of arachnids recorded between 2017 and 2019 in Glasgow Botanic Gardens, Scotland. Species belonging to the orders Araneae (spiders), Opiliones (harvestmen), and Pseudoscorpiones (false scorpions) are included. Notable species are discussed and a comparison is made with prior information on the arachnids of the Gardens.

INTRODUCTION

CC was invited to survey arachnids at the glasshouses and exterior grounds of Glasgow Botanic Gardens (GBG), Scotland as part of the wider project, *On the Wildside Revisited: 200 years of wildlife in the Glasgow Botanic Gardens*, aimed at updating information on the fauna and flora of GBG about 20 years after a similar project (Downie & Forster, 2019). This paper provides an overview of the results of the arachnid surveys. It should be noted that Coleoptera (beetles) and Dictyoptera (cockroaches) collected during these surveys were also identified to species level, and are discussed in other papers in the series (Weddle, 2020; Cathrine, 2022).

Before the investigation described in this paper, only 15 arachnids had been identified to species level and included in Hancock (1999) and the GBG species list (Glasgow Natural History Society, 2017): nine Araneae (spiders), five Opiliones (harvestmen), and one Pseudoscorpiones (false scorpion).

METHODS

Three survey visits were made by the CC to GBG between 2017 and 2018. During each of these, both "pooter" and "bugvac" sample methods (see below) were employed at a variety of sample locations within glasshouses and outdoors. In addition, Andrew Sinclair (Curator, GBG), collected specimens in 2019 which were identified and included in this paper. Specimens were collected from six broad areas which can be summarised as Begonia Backup, Kibble Palace, Main Range (glasshouse), The Long Pit, Gardens (outdoors), Wall (a brick wall, outdoors, to the west of The Long Pit) (Table 1). Ten locations were sampled throughout the exterior gardens, encompassing a range of habitats and situations. These sample location areas are equivalent to those that produced invertebrate records during the original *On the Wildside* project, with the exception of a disused railway station where samples were obtained previously but which could not be accessed during these arachnid surveys. Specimens were preserved in a 70% isopropanol and 30% water mixture for later identification in the laboratory.

The vast majority of spiders require examination of genitals or secondary sexual organs under a microscope in order to confirm species. Although different species have their peak adult season at different times of year, in Scotland the largest number can be found in autumn. Therefore, to maximise the diversity of species recorded with limited survey effort, sampling was undertaken during autumn.

Sample and laboratory identification methods are described in further detail below.

Pooter

Microhabitats were searched by "grubbing" in the ground layer, overturning leaves and stones, and searching deadwood, utilising a pooter to collect fragile invertebrates without damaging the features necessary for identification (Fig. 1A).

Bugvac

A modified petrol-powered leaf blower (Husqvarna 125BVX) was used to vacuum sample invertebrates from ground level (Fig. 1B). Bugvac sampling has proved to be the most effective method of establishing the presence of species that live in less accessible micro-habitats such as the base of vegetation, or for small invertebrates that are often under-recorded by more traditional sampling techniques (Wilson *et al.*, 1993). For example, this method was very effective for detecting the rare *Heliophanus dampfi* (a Red Data Book species), which prefers the bases of *Molinia* (moor-grass) and *Eriophorum* (cotton-grass) tussocks in bog habitats (Cathrine, 2012). Petrol-powered vacuum samplers appear to collect more individuals and species than battery-powered models (Wilson, 2020). Each sample involved pressing the bugvac nozzle to the

Sample Location Area	Grid Reference	Date	Methods
Begonia Backup	NS56856753	01/02/2019	Active search
Gardens	NS5661567563	21/09/2017	Bugvac, pooter
Gardens	NS5661767564	12/10/2018	Pooter
Gardens	NS5661767717	03/08/2018	Bugvac
Gardens	NS5661967573	03/08/2018	Bugvac
Gardens	NS5663067665	03/08/2018	Bugvac
Gardens	NS5664967740	12/10/2018	Pooter
Gardens	NS5665767753	03/08/2018	Bugvac
Gardens	NS5669367550	12/10/2018	Pooter
Gardens	NS5673767498	03/08/2018	Bugvac
Gardens	NS5676967606	12/10/2018	Pooter
Kibble Palace	NS5690167466	12/10/2018	Pooter
Main Range	NS5681367511	21/09/2017	Bugvac
Main Range	NS5681367511	21/09/2017	Pooter
Main Range	NS5681367511	03/08/2018	Pooter
The Long Pit	NS5682067545	03/08/2018	Pooter
Wall	NS5681067573	12/10/2018	Pooter

Table 1. Details of arachnid survey sample locations, Glasgow Botanic Gardens, Scotland. Specimens at Begonia Backup were collected by Andrew Sinclair. Specimens at all other locations were collected by CC.

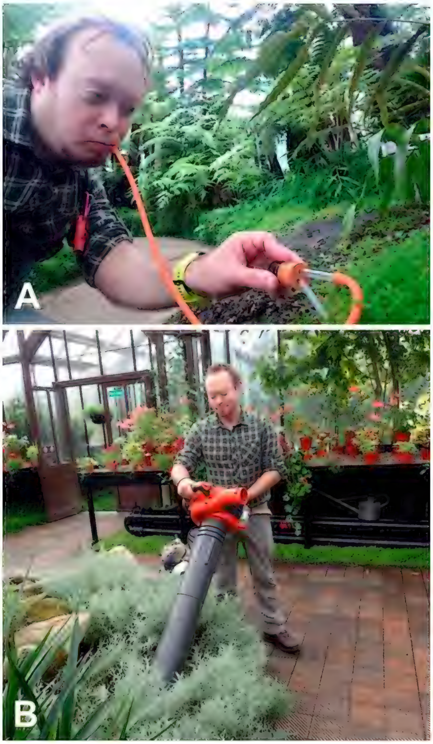

Fig. 1. Sampling methods employed in Glasgow Botanic Gardens, demonstrated by CC. (A) Pooter. (B) Bugvac. (Photos: Richard Weddle)

ground for ten seconds at five points. Specimens were then emptied from the net into a white plastic tray and collected with forceps.

Active search

These specimens were collected opportunistically by Andrew Sinclair.

Laboratory identification

Preserved specimens were identified by KG and CC in the lab with stereo-microscopes. Appropriate references were used for the identification of specimens, and comparisons were made with the Caledonian Conservation Ltd. reference collection where necessary, to confirm identification. Voucher specimens were retained.

RESULTS

A total of 48 arachnid species was recorded and a full species list, including sample locations where they were recorded, is provided in Table 2. The Gardens was the most diverse area, with 38 species of arachnid recorded. Six species were recorded from the Main Range, five from Kibble Palace, four from The Long Pit, two from the Wall, and one from the Begonia Backup. The results for each order are detailed below, with a focus on particularly notable species. It should be noted that only specimens identifiable to species level are included in this paper. In addition, numbers of specimens are not reported here, as the survey was not quantitative and no inference of relative abundance could be made; the results of this survey can only be used to confirm presence.

Order	Family	Species	Rarity Status	Sample Location Area					
				Begonia Backup	*Gardens*	*Kibble Palace*	*Main Range*	*Long Pit*	*Wall*
Araneae	Araneidae	*Araneus diadematus*				▨		▨	
Araneae	Araneidae	*Larinioides sclopetarius*	Very local			▨			
Araneae	Araneidae	*Zygiella x-notata*			▨		▨	▨	
Araneae	Linyphiidae	*Allomengea scopigera*	SAL; local		▨				
Araneae	Linyphiidae	*Bathyphantes gracilis*			▨				
Araneae	Linyphiidae	*Bathyphantes parvulus*			▨				
Araneae	Linyphiidae	*Centromerita bicolor*			▨				
Araneae	Linyphiidae	*Dicymbium nigrum*			▨				
Araneae	Linyphiidae	*Diplocephalus cristatus*			▨				
Araneae	Linyphiidae	*Diplocephalus latifrons*			▨				
Araneae	Linyphiidae	*Drapetisca socialis*			▨				
Araneae	Linyphiidae	*Erigone atra*			▨				
Araneae	Linyphiidae	*Erigone dentipalpis*			▨				
Araneae	Linyphiidae	*Labulla thoracica*							▨
Araneae	Linyphiidae	*Linyphia triangularis*			▨				
Araneae	Linyphiidae	*Neriene clathrata*			▨				
Araneae	Linyphiidae	*Neriene montana*			▨				
Araneae	Linyphiidae	*Oedothorax fuscus*			▨				
Araneae	Linyphiidae	*Palliduphantes ericaeus*			▨				
Araneae	Linyphiidae	*Savignia frontata*			▨				
Araneae	Linyphiidae	*Tenuiphantes alacris*			▨				
Araneae	Linyphiidae	*Tenuiphantes flavipes*			▨				
Araneae	Linyphiidae	*Tenuiphantes mengei*				▨			
Araneae	Linyphiidae	*Tenuiphantes tenuis*			▨				
Araneae	Linyphiidae	*Tenuiphantes zimmermanni*			▨				
Araneae	Linyphiidae	*Tiso vagans*			▨				
Araneae	Lycosidae	*Pardosa amentata*			▨				
Araneae	Oonopidae	*Oonops pulcher*	Local				▨		
Araneae	Philodromidae	*Philodromus aureolus*			▨				
Araneae	Pholcidae	*Pholcus phalangioides*					▨	▨	
Araneae	Salticidae	*Evarcha falcata*	Local				▨		

Araneae	Tetragnathidae	*Metellina segmentata*			▨				
Araneae	Tetragnathidae	*Pachygnatha degeeri*			▨				
Araneae	Tetragnathidae	*Tetragnatha obtusa*	Local			▨			
Araneae	Theridiidae	*Enoplognatha ovata*			▨				
Araneae	Theridiidae	*Paidiscura pallens*			▨				
Araneae	Theridiidae	*Parasteatoda tepidariorum*	Non-native	▨		▨	▨	▨	
Araneae	Theridiidae	*Phylloneta impressa*			▨				
Araneae	Theridiidae	*Rugathodes sexpunctatus*	Non-native		▨				
Opiliones	Gyantinae	*Dicranopalpus ramosus*	Non-native		▨				
Opiliones	Leiobuninae	*Leiobunum rotundum*			▨				
Opiliones	Nemastomatidae	*Nemastoma bimaculatum*			▨				
Opiliones	Phalangiidae	*Mitopus morio*			▨				
Opiliones	Phalangiidae	*Oligolophus tridens*			▨				
Opiliones	Phalangiidae	*Paroligolophus agrestis*			▨				▨
Opiliones	Phalangiidae	*Platybunus triangularis*			▨				
Pseudoscorpiones	Neobisiidae	*Neobisium carcinoides*			▨				
Pseudoscorpiones	Neobisiidae	*Roncus lubricus*	Very local				▨		

Table 2. Arachnid species list for Glasgow Botanic Gardens, Scotland, including sample locations at which each was recorded. Shaded cells indicate a species was recorded at that sample location. "Very local" and "local" descriptions are in the context of Scotland. SAL: spider amber list. See Table 1 for further details regarding sample locations.

Araneae (spiders)

Thirty-nine species of spider were recorded, including one on the Spider Amber List (Harvey *et al.*, 2017), which is also considered to be local (*Allomengea scopigera*), one very local (*Larinioides sclopetarius*), and four local (*Oonops pulcher, Evarcha falcata,* and *Tetragnatha obtusa*) in the context of Scotland. In addition, two non-native species were also recorded - *Parasteatoda tepidariorum* and *Rugathodes sexpunctatus.*

Thirty species of spider were recorded from the Gardens, five from Kibble Palace, five from the Main Range, four from The Long Pit, one from the Wall, and one from the Begonia Backup.

Opiliones (harvestmen)

Seven species of harvestman were recorded, including one introduced species - *Dicranopalpus ramosus*.
Seven species of harvestmen were recorded from the Gardens, and one species was recorded from the Wall. Harvestmen were not recorded from other areas.

Pseudoscorpiones (false scorpions)

Two species of false scorpions were recorded - *Roncus lubricus* and *Neobisium carcinoides*. *R. lubricus* is considered to be very local in the context of Scotland.
R. lubricus was recorded from the Main Range, and *N. carcinoides* from the Gardens. False scorpions were not recorded from other areas.

DISCUSSION

The following sections discuss the notable species found during this arachnid survey for each order, and a comparison is made with the previous knowledge of arachnids in GBG.

Araneae (spiders)

Five notable species of spider were recorded during this survey.

Allomengea scopigera, a linyphiid, is included on the Spider Amber List (Harvey *et al.*, 2017) and has a local distribution in Scotland. This species is found in a range of wet habitats, and was recorded outdoors in the Gardens at GBG (Harvey *et al.*, 2002).

The araneid, *Larinioides sclopetarius*, is generally associated with large trees near water and has a very local distribution in Scotland (Harvey *et al.*, 2002). The combination of warmth and water features at Kibble Palace, where it was recorded, provides an optimal habitat for this species.

Oonops pulcher, which has a local distribution in Scotland, was found in the Main Range. This species is often associated with *Amaurobius* spp., feeding on the remains of prey in their webs (Bee *et al.* 2017). *Amaurobius* spp. are abundant throughout GBG, particularly in the glasshouses. Although specimens belonging to this genus were collected during survey visits, none were mature and so could not be identified to species level.

Evarcha falcata, a jumping spider (Salticidae) associated with woodland, was recorded in the Main Range. Although it is known to occur in Scotland, with a local distribution, it has not been previously recorded from the Glasgow area (Bee *et al.*, 2017).

The tetragnathid spider, *Tetragnatha obtusa*, is found in woodland, and was recorded from Kibble Palace. It has a very restricted distribution in Scotland, is considered to be local, and has not been recorded from the Glasgow area before (Bee *et al.*, 2017).

Two non-native spiders were recorded, both belonging to the family Theridiidae. *Parasteatoda tepidariorum* has been recorded in GBG previously (Hancock, 1999). Although its native range is unclear, it is likely to have originated in the neotropics or warm climate in Asia, and cannot survive outdoors in Scotland (Levi, 1967; Roberts, 1996; Faúndez & Téllez, 2016; Bee *et al.*, 2017; World Spider Catalog, 2022). *P. tepidariorum* was abundant in all interior areas surveyed. *Rugathodes sexpunctatus*, which originates from North America, was first reported from the Glasgow Necropolis in the U.K. in 2012 (although a specimen collected in 2009 was later confirmed to be this species), but has since been found in Dunbartonshire, South Lanarkshire, and Clackmannanshire, so may be more widespread in Scotland than previously thought (Davidson, 2012; Davidson & Merrett, 2014; Cathrine & Currie, 2020; Davidson & Cathrine, 2020). *R. sexpunctatus* was recorded from the exterior Gardens area.

Opiliones (harvestmen)

The introduced species, *Dicranopalpus ramosus*, was found in the Gardens area, and is increasingly widespread in Scotland. However, it has recently been found that *D. caudatus*, previously thought to be synonymous with *D. ramosus*, is a separate species and is also present in the U.K. It has been confirmed that some specimens of *D. caudatus* have been misidentified as *D. ramosus* (Wijnhoven & Prieto, 2015; Davidson, 2019). In the present survey all specimens were confirmed to be *D. ramosus*. This species is largely synanthropic in Scotland (Hillyard, 2005). *D. ramosus* appears to originate from the Iberian Peninsula, France and Morocco but is now widespread throughout Europe (Wijnhoven, 2009).

Pseudoscorpiones (false scorpions)

The record of *Roncus lubricus* at GBG is just the second for Scotland (Gerald Legg, pers. comm.). Based on data held by the Pseudoscorpion Recording Scheme, this is the first record from a glasshouse in Scotland; the previous Scottish record was made on the shore of the Solway in 1998. However, that record of *R. lubricus* was in shingle, while the specimens collected at GBG were found under gravel in the entrance to the Main Range: both microhabitats are similar in structure. This species is found on sea-shores as well as synanthropic situations including glasshouses and old gardens (Legg & Jones, 1988; Legg & Farr-Cox, 2016).

Neobisium carcinoides is the most widespread "species" of false scorpion found in Scotland and is found in almost every habitat including woodland, sea-shore, peatland, grassland, mountain tops, and urban environments. However, recent research has revealed considerable taxonomic complexity. For example, Harvey (2013) lists eight species synonymous with *N. carcinoides* worldwide, whilst Muster *et al.* (2021) found at least 12 putative cryptic species based on DNA barcoding of *N. carcinoides* specimens in Germany. Therefore, there is a high degree of uncertainty over the identification of specimens in this complex pending the publication of further details.

Comparison with previous knowledge of arachnids in Glasgow Botanic Gardens

The results of this survey have increased the total number of arachnid species known from GBG from 15 to 51: the number of Araneae (spiders) has increased from eight to 41, Opiliones (harvestmen) from five to seven, and Pseudoscorpiones (false scorpions) from one to three.

Species previously recorded based on Hancock (1999) and Glasgow Natural History Society (2017) were refound with the exception of three species: two spiders (*Metellina merianae* and *Palystes castaneus*) and one pseudoscorpion (*Ephippiochthonius tetrachelatus*).

Metellina merianae is a species of tetragnathid spider which is extremely similar in appearance to *M. segmentata* which was recorded during this survey. These two species are widespread and common, often coexisting. Although either can be mature in spring, summer, and autumn, *M. merianae* has its adult peak in spring and early summer, whereas mature *M. segmentata* are mostly found during late summer and autumn. Many immature *Metellina* sp. were collected during the *On the Wildside Revisited* surveys, and as only mature specimens were identified some of these may have been *M. merianae*. It is also highly likely that some immature specimens related to *M. mengei*, which is even more similar in appearance to *M. segmentata* and has an adult peak season similar to that of *M. merianae*. It is considered highly likely that *M. merianae* is still present at GBG, and that it was not recorded during this survey due to the visits being undertaken in autumn. Other spider species present at GBG with adult peak seasons outwith autumn may also have been missed.

Palystes castaneus, recorded at GBG in 1863, is native to South Africa, belonging to the family Sparassidae (Croeser, 1996; Hancock, 1999). It is worth noting that the taxonomy relating to this genus has undergone substantial revision since 1863, and it would be worth re-examining the specimen if it has been retained. There are no representatives of Sparassidae occurring in Scotland, as they cannot survive in the Scottish climate. It is likely this record relates to an individual animal, or small number of individuals, transported with a plant specimen (Hancock, 1999), and that this species has not persisted at GBG. The introduction of non-native invertebrates to the GBG was probably not uncommon, particularly historically when biosecurity measures were less robust than in the present day, and there may have been many examples of this for arachnid species which have not been recorded.

Ephippiochthonius tetrachelatus was found in the Main Range in 1988 by Adrian Rundle, who also recorded this species in the People's Palace during the same visit to Glasgow (Richard Weddle, pers. comm.). It has been recorded from scattered locations throughout south, central and western Scotland (Hancock, 1999; Biological Records Centre, 2022). Although often associated with synanthropic situations, including glasshouses, this false scorpion is also found in natural habitats under stones, in leaflitter, and in decaying vegetation. False scorpions can be challenging to collect, and additional survey efforts employing a wide range of methods targeting these animals are likely to find that *E. tetrachelatus* persists and reveal additional species at GBG. Although bugvac is an effective method for collecting false scorpions, the addition of leaflitter sieving, bark traps, artificial bird nest traps, and Tullgren funnels, would provide more robust results for these arachnids.

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The bryophytes of Glasgow Botanic Gardens

K.J. Watson

Glasgow Museums, Art Gallery and Museum, Kelvingrove, Glasgow G3 8AG

E-mail: keith.watson@glasgowlife.org.uk

ABSTRACT

The bryophytes (mosses and liverworts) growing wild in the Glasgow Botanic Gardens, Scotland have not previously been the subject of a detailed survey. As part of the current wildlife surveys of the gardens, recent field visits have attempted to address this shortfall. Records have been made for the general grounds, trees, built infrastructure and the contiguous banks of the River Kelvin, where old woodland and rock exposure occur. During this survey, 70 bryophyte species were found, bringing the total number recorded in the gardens over recent years to 88. Observations from inside the glasshouses indicate that there is potentially high interest in overseas bryophytes brought in with plants. A number of locally rare or uncommon species have been recorded, and of note are two non-native species which appear to be spreading. There remains the potential for more species to be found both about the extensive grounds and inside the glasshouses.

INTRODUCTION

The mosses and liverworts (bryophytes *sensu lato*) of Glasgow Botanic Gardens, Scotland do not appear to have been the subject of a detailed survey by expert bryologists. However, there have been some occasional observations made over the past few decades, and more recent visits by the author have helped to increase the site's total number of mosses and liverworts. There is also considerable interest (known and potential) as regards the bryophytes growing inside the actual glasshouses.

A list of bryophytes occurs in an old publication about the Botanic Gardens (Sherry, 1902), where the species listed are noted as occurring "in various parts of the Greenhouses and the others are under cultivation in the Gardens from time to time". A total of 67 species is listed (11 liverworts, four *Sphagnum* spp. and 52 other mosses). No locations are provided but a list of fungi in the same publication notes locations such as "In Mossery" and "Winter Gardens". It does not appear that this list represents bryophytes found growing wild, and a number of species listed would be highly unlikely to do so, and there are many expected common species that are not listed. However, no non-native species are mentioned.

The gardens support a range of habitats ranging from the garden beds and lawns, to the built infrastructure (outside and inside), and the diverse range of trees. In addition, the northern boundary of the gardens, and the arboretum, occur along the River Kelvin valley with its more semi-natural woodland structure and some rock outcrops.

METHODS

The current survey commenced in late 2018 and involved three visits by the author to the gardens, the latest being in late 2021. Identifications have been from field determination mostly confirmed by later microscopic examination. The author also made casual records following visits in the 1990s and early 2000s (19 of these species were not recorded during the current survey). Additionally there was one record made by Richard Weddle in 2017 and earlier Gerry Rodway made two records in the 1960s.

The following describes some of the bryological features of the different zones in the gardens. The names follow the new 2021 Census Catalogue (Blockeel *et al.*, 2021).

RESULTS

During the recent survey, 70 bryophyte species were found in Glasgow Botanic Gardens, bringing the total number recorded in the gardens over the past *ca.* 60 years to 88 (Table 1). The following discusses some of the bryological features of the different habitats in the gardens. The taxonomy follows Blockeel *et al.* (2021).

Garden beds and lawns

This large area was not sampled in any detail. Because the garden beds are subject to frequent disturbance from gardening activities and are nutrient-enriched, the potential for long established bryophytes is limited, although there is potential for more ephemeral colonists. The latter include frequent common pottia (*Tortula truncata*) and cylindric beard-moss (*Didymodon insulanus*), and locally bulbil-forming mosses such as *Bryum dichotomum* and *Pohlia annotina.* Also on disturbed soil, very small but fruiting pocket-mosses appear to be green pocket-moss (*Fissidens viridulus*). The occasional rockery can provide a more stable niche for bryophyte establishment (see stonework below).

Old plant pot colonists include golden thread-moss (*Leptobryum pyriforme*) and crescent-cup liverwort (*Lunularia cruciata*). *L. pyriforme* was collected from pots in the garden in 1920 by Donald Patton (specimen in the Glasgow University herbarium) and it was also recorded by Gerry Rodway in 1960.

Scientific Name	Common Name	Earliest	Latest	No. of Records
Liverworts				
Calypogeia fissa	common pouchwort	1994	1998	2
Calypogeia muelleriana	Mueller's pouchwort	2021	2021	1
Cephalozia bicuspidata	two-horned pincerwort	1994	1994	3
Conocephalum conicum agg.	great scented liverwort	1994	2021	1
Diplophyllum albicans	white earwort	1994	2021	2
Lophocolea bidentata	bifid crestwort	1994	2018	2
Lophocolea bispinosa	great crestwort	2019	2019	1
Lophocolea heterophylla	variable-leaved crestwort	1994	1994	1
Lunularia cruciata	crescent-cup liverwort	1960	2018	1
Mesoptychia turbinata	top notchwort	2000	2000	2
Metzgeria furcata	forked veilwort	2018	2019	2
Metzgeria violacea	blueish veilwort	2019	2019	1
Pellia endiviifolia	endive pellia	2018	2018	1
Pellia epiphylla	overleaf pellia	1994	1994	1
Radula complanata	even scalewort	2018	2018	1
Scapania nemorea	grove earwort	2021	2021	1
Tricholepidozia tetradactyla	Long's threadwort	2018	2018	1
Mosses				
Amblystegium serpens	creeping feather-moss	1994	2018	3
Atrichum undulatum	common smoothcap	1994	2018	2
Barbula unguiculata	bird's-claw beard-moss	2019	2019	1
Brachytheciastrum velutinum	velvet feather-moss	1994	1994	1
Brachythecium rutabulum	rough-stalked feather-moss	1994	2018	3
Bryoerythrophyllum recurvirostrum	red beard-moss	2018	2018	1
Bryum alpinum	alpine thread-moss	1994	1994	1
Bryum argenteum	silver-moss	1994	2018	2
Bryum capillare	capillary thread-moss	1994	2018	3
Bryum dichotomum	bicoloured bryum	1995	2021	1
Calliergonella cuspidata	pointed spear-moss	1994	2018	2
Campylopus introflexus	heath star moss	1994	2018	3
Ceratodon purpureus	redshank	1994	2018	2
Cirriphyllum piliferum	hair-pointed feather-moss	2021	2021	1
Cratoneuron filicinum	fern-leaved hook-moss	1997	1998	1
Dichodontium pellucidum	transparent fork-moss	1994	2018	3
Dicranella cerviculata	red-neck forklet-moss	1963	1963	1
Dicranella heteromalla	silky forklet-moss	2018	2018	1
Dicranoweisia cirrata	common pincushion	1994	2018	2
Dicranum scoparium	broom fork-moss	1994	1994	1
Didymodon insulanus	cylindric beard-moss	1994	2018	3
Ditrichum heteromallum	curve-leaved ditrichum	2018	2018	1
Eucladium verticillatum	whorled tufa-moss	1994	1998	4
Fissidens bryoides	lesser pocket-moss	1994	2018	4
Fissidens dubius	rock pocket-moss	2021	2021	1
Fissidens taxifolius	common pocket-moss	2018	2018	1
Fissidens viridulus sensu lato	green pocket-moss	2021	2021	1
Grimmia pulvinata	grey-cushioned grimmia	2018	2018	1
Homalia trichomanoides	blunt feather-moss	2019	2021	2
Hygroamblystegium fluviatile	brook-side feather-moss	2019	2019	1
Hypnum andoi	mamillate plait-moss	1994	2018	2
Hypnum cupressiforme var. *cupressiforme*	cypress-leaved plait-moss	1994	2018	2
Kindbergia praelonga	common feather-moss	1994	2018	3
Leptobryum pyriforme	golden thread-moss	1960	2018	2
Lewinskya affinis	wood bristle-moss	2018	2019	2
Mnium hornum	swan's-neck thyme-moss	1994	2018	2

Orthodontium lineare	cape thread-moss	2000	2000	2
Orthotrichum anomalum	anomalous bristle-moss	2018	2018	1
Orthotrichum diaphanum	white-tipped bristle-moss	2018	2019	2
Orthotrichum tenellum	slender bristle-moss	2019	2019	1
Oxyrrhynchium hians	Swartz's feather-moss	2000	2018	3
Philonotis fontana	fountain apple-moss	2018	2018	1
Plagiomnium rostratum	long-beaked thyme-moss	2019	2021	2
Plagiomnium undulatum	hart's-tongue thyme-moss	2018	2018	1
Plagiothecium succulentum	juicy silk-moss	1994	1998	3
Plenogemma phyllantha	frizzled pincushion	2018	2018	1
Pogonatum urnigerum	urn haircap	2021	2021	1
Pohlia annotina	pale-fruited thread-moss	2018	2018	1
Polytrichum formosum	bank haircap	1994	1994	1
Polytrichum longisetum	slender haircap	2018	2018	1
Polytrichum commune	common haircap	2018	2018	1
Pseudotaxiphyllum elegans	elegant silk-moss	1994	1994	1
Racomitrium aciculare	yellow fringe-moss	2019	2019	1
Rhizomnium punctatum	dotted thyme-moss	2017	2017	1
Rhynchostegium confertum	clustered feather-moss	1994	2019	8
Rhynchostegium riparioides	long-beaked water feather-moss	2019	2019	1
Rhytidiadelphus squarrosus	springy turf-moss	2018	2018	1
Schistidium apocarpum sensu lato	sessile grimmia	2018	2018	1
Schistidium crassipilum	thickpoint grimmia	2018	2018	1
Schistidium rivulare	river grimmia	2019	2019	1
Streblotrichum convolutum	lesser bird's-claw beard-moss	2018	2018	1
Syntrichia latifolia	water screw-moss	2018	2018	1
Tetraphis pellucida	pellucid four-tooth moss	1997	1998	1
Thamnobryum alopecurum	fox-tail feather-moss	2018	2019	2
Tortula muralis	wall screw-moss	2018	2018	1
Tortula truncata	common pottia	2021	2021	1
Ulota bruchii	Bruch's pincushion	2021	2021	1
Weissia controversa	green-tufted stubble-moss	2018	2019	1
Zygodon conoideus	lesser yoke-moss	2018	2018	1
Zygodon rupestris	park yoke-moss	2021	2021	1
Zygodon viridissimus	green yoke-moss	2000	2001	2

Table 1. Liverworts and mosses recorded from Glasgow Botanic Gardens, Scotland. All records by the author except those for 2017 (by Richard Weddle) and the 1960s (by Gerry Rodway).

The lawns are well manicured and the majority remain short-cropped all year, but some are well shaded. A typical range of mosses occurs including the often abundant springy turf-moss (*Rhytidiadelphus squarrosus*) and, less abundantly, common feather-moss (*Kindbergia praelonga*); in shaded locations hart's-tongue thyme-moss (*Plagiomnium undulatum*) can be prominent and pointed spear-moss (*Calliergonella cuspidata*) picks out poorly draining areas.

Trees

Of particular interest are the mature trees along the open avenues (where there tends to be more light, in contrast to shaded woodland areas). Here, typical common epiphytes on the trunks are found, such as mamillate plait-moss (*Hypnum andoi*), common pincushion (*Dicranoweisia cirrata*), wood bristle-moss (*Lewinskya affine*), capillary thread-moss (*Bryum capillare*) and the liverwort forked veilwort (*Metzgeria furcata*). Other less common (or less commonly recorded) finds include yoke-mosses (*Zygodon* spp.), frizzled pincushion (*Plenogemma phyllantha*), white-tipped bristle-moss (*Orthotrichum diaphanum*), water screw-moss (*Syntrichia latifolia*) and the liverwort even scalewort (*Radula complanata*).

Built Infrastructure

The outside brick and mortar walls, and metalwork, and associated infrastructure present hard structures for some colonists. Stone or brick substrates (including some rockery stones) support grey-cushioned Grimmia (*Grimmia pulvinata*), wall screw-moss (*Tortula muralis*), thickpoint Grimmia (*Schistidium crassipilum*), anomalous bristle-moss *(Orthotrichum anomalum),* cylindric beard-moss *(Didymodon insulanus),* green-tufted stubble-moss (*Weissia controversa* s.l.) and curve-leaved ditrichum (*Ditrichum heteromallum*). Roofs and some paths support the diminutive silver-moss (*Bryum argenteum*) with its distinctive silvery leaf tips.

A small crestwort (*Lophocolea* sp.) liverwort growing on a crumbling south-facing wall behind the potting sheds was collected and has been confirmed as the rare *L. bispinosa*, a non-native species known from the southern hemisphere. The plants examined were all male.

A flooded gutter of one glasshouse supports mats of common haircap (*Polytrichum commune*), but one fruiting population proved to be the locally rare slender haircap (*P. longisetum*) in a most unusual location.

The Kibble Palace was the subject of interest last century with the finding of a couple of exotic species. *Hypopterygium atrotheca* (now known as *H. tamarisci*) was described by H.N. Dixon from material sent to him from the "fernery" by Robert Grierson in1928. The *Hypopterygium* was first collected by James Stirton back in 1913, and it can still be seen today in the Filmy Fern House. More recently *Zoopsis liukiuensis* was found growing on tree fern stems (Wallace, 1976). On a recent brief visit to the Filmy Fern House a number of luxurious thalloid liverworts could be readily seen growing amongst the ferns, including a *Marchantia* sp. and a probable relative of veilwort (family *Pallaviciniaceae*) such as a *Symphyogyna* sp. Other liverworts noted here include a pouchwort (*Calypogeia* sp.), which is close to *C. neesiana*, and a crestwort (*Lophocolea* sp.) relative, similar to *Heteroscyphus tridentatus* (from south-east Asia).

Banks of River Kelvin

Along the northern boundary of the core gardens the riverbank slope supports dense woodland. Here, a number of exotic trees and shrubs on the upper bank grade to more semi-natural woodland on the lower and steeper slopes. However, being north-facing and with often much beech (*Fagus sylvatica*) and some evergreen shrubs, the ground flora is heavily shaded.

Shaded old stumps and branches are usually carpeted in bryophytes, often much rough-stalked feather-moss (*Brachythecium rutabulum*) and common feather-moss (*Kindbergia praelonga*) with some clustered feather-moss (*Rhynchostegium confertum*), cypress-leaved plait-moss (*Hypnum cupressiforme*), creeping feather-moss (*Amblystegium serpens*) plus the crestworts *Lophocolea bidentata* and *L. heterophylla*

On the ground and often about tree bases, in usually damp and clayey places, mosses include hart's-tongue thyme-moss (*Plagiomnium undulatum*), common smoothcap (*Atrichum undulatum*), swan's-necked thyme-moss (*Mnium hornum*), cylindric beard-moss (*Didymodon insulanus),* lesser pocket-moss (*Fissidens bryoides*), common pocket-moss (*F. taxifolius*), and thalloid liverworts such as great scented liverwort (*Conocephalum conicum* s.l.), crescent-cup liverwort (*Lunularia cruciata)* and *Pellia* spp.

The inundated rocks and tree roots by the water's edge were briefly sampled and revealed a range of aquatic influenced species, including long-beaked water feather-moss (*Rhynchostegium riparioides*) and river Grimmia (*Schistidium rivulare*), and occasionally brook-side feather-moss (*Hygroamblystegium fluviatile*) and on tree roots blunt feather-moss (*Homalia trichomanoides*).

Records of local interest from the valley slopes, often on rock outcrops, include whorled tufa-moss (*Eucladium verticillatum*), rock pocket-moss (*Fissidens dubius*) and the liverworts top notchwort (*Mesoptychia turbinata*) and grove earwort (*Scapania nemorea*), several being indicators of more basic rocks. An *Orthodontium* sp. was found at one sandstone outcrop fuelling speculation that it could be the now very rare native thread-moss *Orthodontium gracile,* but unfortunately sectioning of the nerve showed it to be the spreading non-native cape thread-moss (*O. lineare*).

Of particular interest were a few glistening pale green patches on clayey soils of the embankment by the footpath below the filmy fern houses. Closer inspection revealed them to be a tiny liverwort with deeply divided leaves, which appeared to be a threadwort (*Telaranea* spp.). DNA analysis at the Royal Botanic Garden Edinburgh confirmed it as being the recently renamed Long's threadwort (*Tricholepidozia tetradactyla*), a very rare non-native liverwort with only two previous British records, both from botanic gardens: one at the Royal Horticultural Society Garden at Wisley, Surrey, England and the other from the Younger Botanic Garden (Benmore Botanic Garden) near Dunoon, Argyll, Scotland. DNA analysis revealed it be an exact match with plant material from the latter location. Inspection of the author's past collections revealed that a puzzling sample of an unnamed member of family *Lepidoziaceae* ("*Kurzia* sp."), found on the Kelvin banks at Kelvingrove (a mile or so downriver) in 2016, was in fact the same species indicating its ability to spread widely and amplifying the interest of this find.

CONCLUSIONS

The list in Table 1 is a further example of the wide diversity of taxa to be found in Glasgow Botanic Gardens as other papers in this series have revealed. However, given the range of habitats present it is likely that the total could be increased with more detailed sampling.

A good range of commoner species is to be found as well as number of species of local interest, ranging from native relics to species from overseas. The *Lophocolea bispinosa* and *Tricholepidozia tetradactyla* finds are of special local note, but it might be expected that other exotic colonists are to be found in or near the gardens. The interiors of the actual glasshouses in particular would reward the more enthusiastic expert bryologist, but there remains plenty of scope for finding new and interesting records both in and around the gardens.

ACKNOWLEDGEMENTS

I am grateful to Nick Hodgetts for confirming several records and for attempting to put names to several small scraps that could have originated from potentially anywhere around the globe! I am also grateful to Laura Forrest of the Royal Botanic Garden Edinburgh for carrying out the DNA analysis, and to Richard Weddle for supplying the old list of bryophytes in cultivation at the gardens, and for supplying the records and dates from the Glasgow Museums Biological Records Centre database listed in Table 1.

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The turtles (Testudines) of Glasgow Botanic Gardens including the first record of *Mauremys reevesii* (Gray, 1831) for the U.K. outwith captivity

C. Cathrine* & T. Monir

Caledonian Conservation Ltd., Office 2 and 3,
Craigarnhall, Bridge of Allan, Stirling FK9 4NG

*E-mail: chris.cathrine@caledoniancoinservation.co.uk

This Short Note provides information on the turtles (Testudines) of Glasgow Botanic Gardens, Scotland (GBG).

It first came to CC's attention on 19th January 2022 that there were several terrapins (a polyphyletic group of freshwater turtles belonging to Order Testudines) present in a greenhouse (NS5681467536) to the north of The Main Range at GBG. These terrapins seem not to have been recorded previously, although this is likely to be due to the fact the greenhouse in which they are located is not accessible to the general public. It was evident that at least three types were present.

CC and TM conducted a thorough survey of the terrapins on 26th January. A net was used to extract them from the water troughs in which they were living, and detailed photographs were taken to allow identification. Identification was undertaken by CC and TM, who consulted relevant experts (acknowledged below), and confirmed using keys (CITES, 1999; Virginia Herpetological Society, 2020). Stevie Jakusz (GBG) informed the authors that the turtles had been retrieved from the publicly accessible parts of the Gardens, having presumably been released as unwanted pets.

Two species of terrapin were confirmed to be present at GBG – *Trachemys scripta* (Schoepff, 1792) and *Mauremys reevesii* (Gray, 1831). This appears to be the first record of *M. reevesii* in the U.K.

It should be noted that terrapin eggs were found in the greenhouse during a follow up survey visit by CC on 8th May 2022. Terrapin eggs had been found previously but failed to develop, suggesting conditions are not suitable for breeding (Stevie Jakusz, pers. comm.).

Trachemys scripta

Two subspecies of *T. scripta* were confirmed to be present at GBG – *T. scripta elegans* (two individuals) (Fig. 1) and *T. scripta scripta* (four individuals) (Fig. 2), which have both been recorded infrequently in Scotland, including the Glasgow area (Glasgow Museums Biological Records Centre (GMBRC); McInerny & Minting, 2016; Cathrine, 2021). The five eggs found on 8th May (Fig. 3) had a mean length of 42.5 mm, which is within the range 23.5-44.2 mm reported for *T. scripta* (Dundee & Rossman, 1989). They are therefore considered likely to relate to this species, and so are derived from either *T. scripta elegans* or *T. scripta scripta* present in the greenhouse.

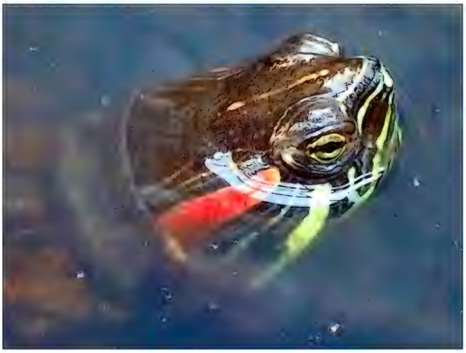

Fig. 1. Red-eared slider (*Trachemys scripta elegans*), Glasgow Botanic Gardens, Scotland. (Photo: Chris Cathrine)

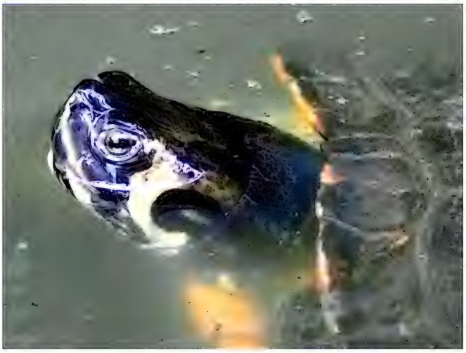

Fig. 2. Yellow-bellied slider (*Trachemys scripta scripta*), Glasgow Botanic Gardens, Scotland. (Photo: Chris Cathrine)

T. scripta, often referred to as the "common slider", is a species of terrapin native to south-eastern and central U.S.A. and northern Mexico (Seidel & Ernst, 2006). There are three described subspecies – *T. scripta elegans* (Wied-Neuwied, 1839) (red-eared slider), *T. scripta scripta* (Schoepff, 1979) (yellow-bellied slider), and *T. scripta troostii* (Holbrook, 1836) (Cumberland slider) (Seidel & Ernst, 2006). All are known from the U.K., but *T. scripta elegans* is by far the most commonly encountered, followed by *T. scripta scripta* (Allain, 2019). This is unsurprising, given these turtles arrive in the wild as a result of the exotic pet trade: *T. scripta elegans* is the most attractively marked sub-species, followed by *T. scripta scripta*, with

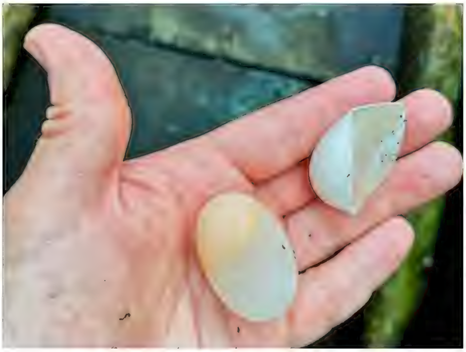

Fig. 3. Common slider (*Trachemys scripta*) eggs, Glasgow Botanic Gardens, Scotland. These could be eggs of the red-eared (*T. scripta elegans*) or yellow-bellied (*T. scripta scripta*) subspecies. (Photo: Chris Cathrine)

T. scripta troostii being largely dull with fewer markings - although some do have spectacular green carapaces, they can also be brown with variable patterning.

T. scripta is included in the IUCN list of the 100 most invasive species, and now occurs in many countries, including within the European Union where its import has been banned due to the establishment of wild populations with an expanding range (Lowe *et al.*, 2000; Kopecky *et al.*, 2013; Allain, 2019). However, the climate in the U.K. is unsuitable for breeding, meaning populations are limited by individual lifespans, although this species can live for over 20 years, and as long as 40 years in exceptional cases. They can therefore persist in a waterbody for a lengthy period depending on the age of the animals when they were released or escaped from captivity (Wareham, 2008; Myhrvold *et al.*, 2015; McInerny & Minting, 2016; Allain, 2019).

Mauremys reevesii

A single specimen of *M. reevesii* was found at GBG (Figs. 4 and 5). This species does not appear to have been reported from the U.K. previously. The eggs recorded on 8th May were considerably longer than the mean length of *M. reevesii* eggs reported as 34.0 mm and 35.0 mm by Yi *et al.* (2019) and Zhao *et al.* (2013) respectively. It is therefore considered unlikely the eggs recorded on 8th May relate to this species.

M. reevesii, commonly known as the "Chinese pond turtle", is a species of terrapin found in China, Taiwan, the Korean Peninsula (excluding Jeju Island), and Japan, although recent genetic studies indicate it is likely to have been artificially introduced to the latter country (van Dijk, 2011; Suzuki *et al.*, 2011; Oh *et al.*, 2017; Rhodin *et al.*, 2021). This species is known to have established introduced populations in Timor-Barat (Indonesia), Timor-Leste, Palau, Spain, and the U.S.A. (Kaiser *et al.*, 2010; van Dijk, 2011; Poch *et al.*, 2020). Furthermore it has recently been found in Ireland (Rob Gandola, pers. comm.).

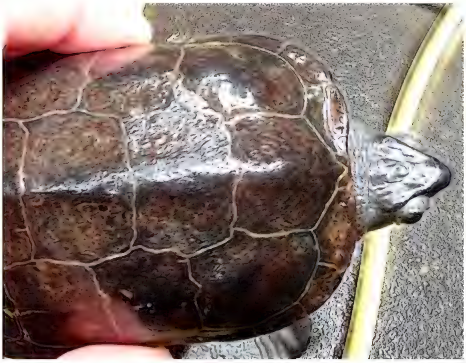

Fig. 4. Chinese pond turtle (*Mauremys reevesii*), Glasgow Botanic Gardens, Scotland; dorsal view, including carapace. (Photo: Chris Cathrine)

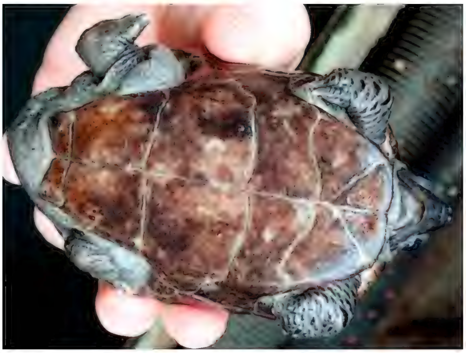

Fig. 5. Chinese pond turtle (*Mauremys reevesii*), Glasgow Botanic Gardens, Scotland; ventral view, including plastron. (Photo: Chris Cathrine)

Populations of *M. reevesii* have declined significantly in their natural range due to a variety of factors including habitat destruction and fragmentation, water pollution from industrial development, use in traditional Chinese medicine, and, more recently, the introduction of invasive non-native species – *T. scripta elegans* in particular (van Dijk, 2011; Oh *et al.*, 2017; Jo *et al.*, 2017; Koo *et al.*, 2019). The larger *T. scripta elegans* has been found to outcompete and exclude the smaller *M. reevesii*, presenting a further threat to this endangered species (van Dijk, 2011; Oh *et al.*, 2017; Jo *et al.*, 2017; Koo *et al.*, 2019). As such, *M. reevesii* is included on the International Union for Conservation of Nature (IUCN) Red List as Endangered and is also listed on Appendix III of the Convention on International Trade in Endangered Species (CITES) of Wild Flora and Fauna, restricting international sale (van Dijk, 2011; CITES, 2015).

Mauremys spp. terrapins are currently being promoted within the exotic pet trade as smaller and less invasive alternatives to *T. scripta*. It may indeed be the case that these terrapins are less invasive than *T. scripta* – an assessment of risk of exotic freshwater turtles within the

European Union (undertaken prior to Brexit, and so including the U.K.) being invasive found *Trachemys scripta* to be of "moderate" risk, whereas *M. reevesii* and *M. sinensis* were considered to be of "low" risk (Kopecky *et al.*, 2013). However, *M. reevesii* has established populations outwith its native range elsewhere in the world, and is considered to be Endangered under the IUCN Red List with their trade as pets restricted under Appendix III of CITES which casts significant doubts over the sustainability or ethicality of this species within the pet trade unless the lineage of the individual can be linked unambiguously to legitimate captive breeding.

It is unlikely that *M. reevesii* would establish functional populations in the U.K., as the climate is even less suitable for this species than for *T. scripta*, but individuals may persist outdoors for a considerable period, as this terrapin is known to live for over 20 years (Kopecky *et al.*, 2013; Myhrvold *et al.*, 2015). Indeed, one of the threats to natural populations of *M. reevesii* and its introduction to areas outwith its native range is its use in traditional Chinese medicine due to its renowned longevity. Recent genetic studies suggest it may possess longevity-related genes (Kaiser *et al.*, 2010; van Dijk, 2011; Yin *et al.*, 2016).

The authors would like to thank Stevie Jakusz and Andrew Sinclair at GBG for their assistance in arranging access and providing useful background information. Particular thanks are also due to those experts who assisted with the identification of the terrapins: Javed Ahmed, Steven Allain, Dan Davis, Rob Gandola, Chris Newman, Pete Minting, Ashley Ogilvie, and Chris Rockett. The authors are also grateful to Euan Murray for his assistance in photographing the turtles, Richard Weddle for his constructive suggestions, Glasgow Museums Biological Records Centre for assistance with relevant data for the local area. Thanks are also due to Debby Lipschutz, Logan Cathrine, and Ross Cathrine for their support on the follow up visit on 8th May. Finally, acknowledgement is due to Caledonian Conservation Ltd. which provided staff time and resources as part of its Corporate Social Responsibility and dedication to furthering our knowledge of the natural world to benefit people and wildlife.

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The cockroaches (Dictyoptera) of Glasgow Botanic Gardens with a summary of the known distribution of *Periplaneta americana* (Linnaeus, 1758) and *P. australasiae* (Fabricius, 1775) in Scotland

C. Cathrine

Caledonian Conservation Ltd., Office 2 and 3,
Craigarnhall, Bridge of Allan, Stirling FK9 4NG

E-mail: chris.cathrine@caledoniancoinservation.co.uk

This Short Note provides information on the Dictyoptera (cockroaches) of Glasgow Botanic Gardens (GBG), these insects having been omitted from previous papers in the *On the Wildside Revisited* series, and summarises information on the wider distribution of cockroaches in Scotland.

Four cockroach specimens were collected in 2017 and 2018 during arachnid surveys in the Main Range glasshouse of GBG (NS5681367511), using the vacuum mode of a modified petrol-powered leaf blower (Husqvarna 125BVX). Full details of survey methods can be found in Cathrine *et al.* (2022). Although the majority of the specimens were immature and therefore very challenging to confirm reliably to species, two adults collected on 21st September 2017 were identified as *Periplaneta australasiae* (the Australian cockroach) by the author using a stereo-microscope with the aid of Choate *et al.* (2013). Fig. 1 shows a specimen of *P. australasiae* photographed in GBG in 2022.

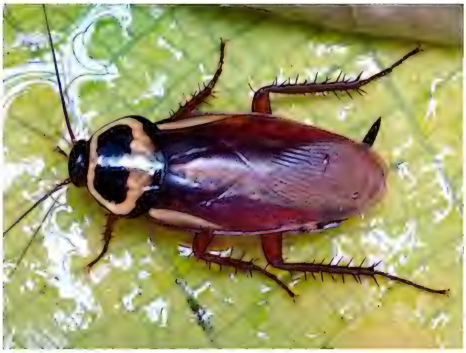

Fig. 1. Australian cockroach (*P. australasiae*), Glasgow Botanic Gardens glasshouse, Scotland, 19th January 2022. (Photo: C. Cathrine)

Prior to the recent surveys, two species of cockroach had been recorded in GBG: *P. americana* (American cockroach) and *P. australasiae* (Hancock, 1999; Glasgow Natural History Society, 2017; Glasgow Museums Biological Records Centre (GMBRC)). *P. americana* was last recorded at GBG in 1902, whereas *P. australasiae* was last found in 1988 and confirmed to still be present during the surveys described in this Short Note (Glasgow Natural History Society, 2017; GMBRC).

Interspecific competition is known to occur between *P. americana* and *P. australasiae*. However, Boyer & Rivault (2004) found that *P. americana*, the larger of the two species, was successful in competition for shelter and food when competing with *P. australasiae*. As such, it seems unlikely that the arrival of *P. australasiae* would have resulted in the exclusion and subsequent replacement of *P. americana* at GBG. The loss of *P. americana* from GBG remains unexplained – it is possible more thorough targeted Dictyoptera surveys may find populations of this species persist at GBG. It is also conceivable that the *Periplaneta* specimens collected from GBG in 1901 and 1902 were misidentified, as *P. americana* and *P. australasiae* can be very similar in appearance. If they have been retained, these specimens should be re-examined to confirm their identity.

Both *P. americana* and *P. australasiae* are known from other locations in Glasgow. Based on GMBRC data, there are five records of *P. americana* from locations outwith GBG including Ibrox (1980), Kelvingrove Museum (1980, 1981, and 1982), and University Avenue (1967). *P. australasiae* has been recorded more frequently, with seven records from elsewhere in Glasgow including Kelvingrove Museum (1980 and 1981), the People's Palace (2015), and Tollcross Park Winter Gardens (1988). Anecdotal evidence suggests that cockroaches may be more widely distributed across the city than these records imply (e.g. Russell, 2017).

Beyond Glasgow, the nearest records of either species are from Paisley where *P. australasiae* has been recorded four times, at various locations (BRC, 2017; GMBRC). There are several records of *P. australasiae* from Edinburgh Botanic Gardens between 1901 and 2015, as well as one of *P. americana* in 1901 – the latter species also having been recorded in Edinburgh Zoo in 2015 (BRC, 2017; Grasshopper Recording Scheme, 2021). In a wider Scottish context, *P. americana* has also been recorded twice in Dundee, in 1971 and 1972 (BRC, 2017). Elsewhere in Scotland, *P. australiase* has been found in Lochinver, Sutherland in 2010 (specimens found in furniture which had arrived from the Far East via London) and Stenness, Orkney, in 1988 (BRC, 2017; Highland Biological Recording Group, 2021).

All records of *P. americana* and *P. australasiae* relate to synanthropic situations – these species are not native to Scotland and cannot survive beyond indoor habitats created by humans.

The author would like to thank Kirsty Godsman for being a helpful sounding board, Richard Weddle for his constructive suggestions, Glasgow Museums Biological Records Centre for assistance with relevant data for the local area, and Euan Murray for his assistance with the photography.

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SHORT NOTES

https://doi.org/10.37208/tgn27412

Liposcelis pubescens (Psocoptera: Liposcelididae): an under-recorded British booklouse in Glasgow, Scotland

R.B. Weddle

89 Novar Drive, Glasgow G12 9SS

E-mail: richard@canto.plus.com

Booklice and barklice (Psocoptera) are small to minute insects (Fig. 1), some with wings and others without, that live in vegetation or among dried materials. The subject of this Short Note – the booklouse *Liposcelis pubescens* Broadhead, 1947 - was first found on "dusty shelves and old paper" at the Biology Field Station cellar at Slough, Berkshire, England on 10th March 1943 (the type locality), and again on 16th April that year at Millwall Central Granary, London. The specimens are in the spirit collection at the Natural History Museum (NHM) in London (P. Brown, pers. comm.). NHM also have specimens from a London SW11 "household" on 14th October 1980 and from Camelford, Cornwall, England in an egg custard mix from 1981. There are no occurrences shown on the NBN Gateway (NBN, 2021), and there are no specimens in the collections at the National Museum of Scotland (NMS), though they have the records and collection donated by the late organiser of the U.K. Psocoptera recording scheme, Bob Saville (A. Whiffin, pers. comm.)

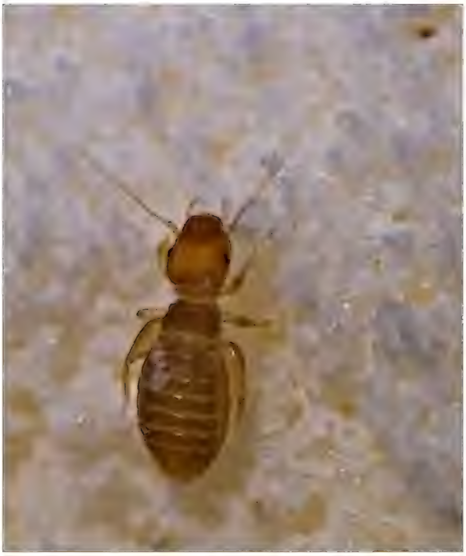

Fig. 1. *Liposcelis* sp. In flour, Manheim-Vogelstang, Baden-Württemberg, Germany, 5th November 2017; size *ca.* 1 mm. (Photo: Andreas Eichler, https://creativecommons.org/licenses/by-sa/4.0/deed.en)

It is therefore surprising to be able to report the presence of thriving populations of *L. pubescens* in a kitchen cupboard at the author's address (see above) in October 2019 during renovations. The populations were in an opened, but long-neglected, bag of plain flour (best-before date 2014), and a partly-used packet of vegetable suet of similar age. In both, the presence of the booklice was signalled by a layer of "caking" on the top surface of the contents of the packets, though there were also vacated lepidopteran pupae in the flour.

Having identified the insect to genus level, I sent the specimens, as advised by the identification key (BRC, 2019) to Charles Lienhard, an Honorary Curator of Arthropoda at the Geneva Museum, Switzerland. I sent about a dozen specimens, which Dr Lienhard identified as *L. pubescens*; both males and females were present. Further specimens from the same populations were donated to the Hunterian Museum in Glasgow.

This seems to be another example of an under-recorded species, though from a generally under-recorded taxonomic order in the U.K. Turner & Bishop (1998) examined 727 yeast trap samples from households throughout the U.K.; of these households, 186 had *L. bostrychophila*, which is a common pest of stored products, whereas only two specimens of *L. pubescens* were found during the survey. This demonstrates the relative rarity of the latter across the U.K. It is rather small (*ca.* 1 mm in length) and wingless; the better-recorded species of barklice tend to be winged and found outdoors on trees, as the alternative common name "barkfly" would suggest. However, the common name "booklouse" generally refers to the wingless indoor species, particularly of the genus *Liposcelis*, which are typically found feeding on books, particularly on the starch used in the bindings, or on moulds growing in the bindings, though they are also known as pests of stored food products (Turner, 1994).

I am grateful to Paul Brown (NHM) for details of their specimens of this species, to Charles Lienhard for identifying the specimens, and to Ashleigh Whiffin for checking the Saville Collection at National Museums Scotland.

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Pugsley's marsh-orchid (*Dactylorhiza traunsteinerioides*) on the Mull of Kintyre, Argyll, Scotland

C.J. McInerny

School of Life Sciences, University of Glasgow,
Glasgow G12 8QQ

E-mail: chris.mcinerny@glasgow.ac.uk

One of the rarest and most localised of the *Dactylorhiza* marsh-orchids in Britain and Ireland is the endemic Pugsley's marsh-orchid (*D. traunsteinerioides*) (BSBI, 2021; NBN, 2021). Its rarity, coupled with a fluctuating taxonomic status over the years, has resulted in the species acquiring an enigmatic and even legendary status (Pugsley, 1936; Allan & Woods, 1993; Harrap & Harrap, 2009; Stace, 2019; Cole & Walker, 2020).

The species has been reclassified multiple times, reflecting the observation that it is a relatively newly formed taxon descended from multiple hybridisation events between common-spotted orchids (*D. fuchsii*) and early marsh-orchids (*D. incarnata*) (Cole & Walker, 2020).

For a period Pugsley's marsh-orchid was given full specific status as *D. traunsteinerioides*, with those in north-west Scotland and some in the Republic of Ireland and Northern Ireland ascribed to the subspecies *D. t. lapponica* and named Lapland marsh-orchid (Harrap & Harrap, 2009). However, later genetic studies indicated that it was instead a *traunsteinerioides* subspecies of the narrow-leaved marsh-orchid *D. majalis*, restricted to north-west Scotland, northern England, Wales, and the northern half of the island of Ireland (Hedrén *et al.*, 2011). The same study also suggested that another subspecies - *D. m. ebudensis* found on North Uist, Outer Hebrides, Scotland - is genetically similar to *D. m. traunsteinerioides*, and that plants in southern England previously thought to be Pugsley's marsh-orchids are instead more closely related to another subspecies *D. m. praetermissa*.

Subsequent genetic analyses revised the taxonomy to indicate that plants in northern Scotland and possibly Northern Ireland were a subspecies - *francis-drucei* - of *D. traunsteinerioides* and named narrow-leaved marsh-orchid (Bateman & Denholm, 2012; Stace, 2019). However, the most recent classification has reverted full circle to giving it full specific status again as *D. traunsteinerioides* and named Pugsley's marsh-orchid, with plants present in western Scotland, northern Wales, the Republic of Ireland, Northern Ireland and northern England, but those in south-east England of uncertain status (Cole & Walker, 2020). This publication also concludes that the Hebridean marsh-orchid, at one time given full specific status as *D. ebudensis*, is a coastal ecotype of Pugsley's marsh-orchid.

I have visited a site on the Mull of Kintyre, Argyll three times over the past five years where a small population of Pugsley's marsh-orchid is present; the precise location is withheld for their protection. As relatively few photographs of *D. traunsteinerioides* from this area have been published and they are highly distinctive, a few images are reproduced with this Short Note (Figs. 1 and 2). Furthermore, some comments on their distinctive appearance, growth period and habitat requirements are provided. Combined, this information may allow interested observers to discover Pugsley's marsh-orchids in new areas in north-west Scotland; this seems possible as the taxon is likely under-recorded, being present in remote places, and is easily overlooked.

Pugsley's marsh-orchid has a strikingly early flowering period for an orchid in north-west Scotland, from mid-May to mid-June, well before other *Dactylorhiza* orchids in the region. On my first visit to the site on 2nd July 2016 I could only find one plant whose flowering period was well "over". My second visit on 18th June 2017 revealed about ten orchids which had finished flowering, with just two still in flower that had been heavily shaded by surrounding tall grass (Fig. 1A-C).

The third visit on 4th June 2021 revealed around 15 spikes which were all in full flower (Fig. 2A-E). The spring of 2021 had an extended period of cool weather during May which may have delayed development of the plants, and so in a more typical year they may flower even earlier from mid-May. In early June 2021 very few other *Dactylorhiza* orchids were in flower at the site which holds common-spotted orchids, heath spotted-orchids (*D. maculata*), early marsh-orchids and heath-fragrant orchids (*Gymnadenia borealis*), which all flower later in the season. Hence, any "purple" orchid flowering during mid to late May in north-west Scotland should be carefully scrutinised.

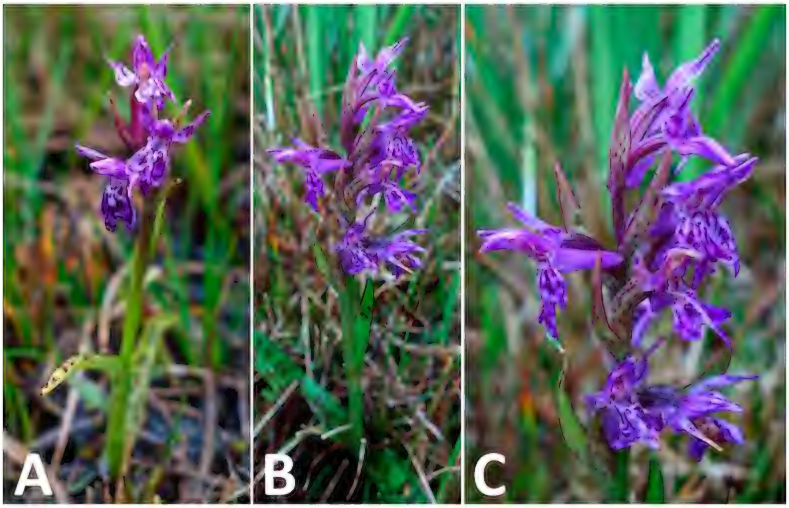

Fig. 1. Pugsley's marsh-orchid (*Dactylorhiza traunsteinerioides*), Mull of Kintyre, Argyll, Scotland, 18th June 2017. These photos show a number of features that identify this distinctive species, which are described in detail in the text. But note the small, lopsided flower head, heavily spotted leaves and complex deep purple lines on the flower lips and sepals. Note that (C) is an enlargement of (B) to reveal flower detail. (Photos: C.J. McInerny)

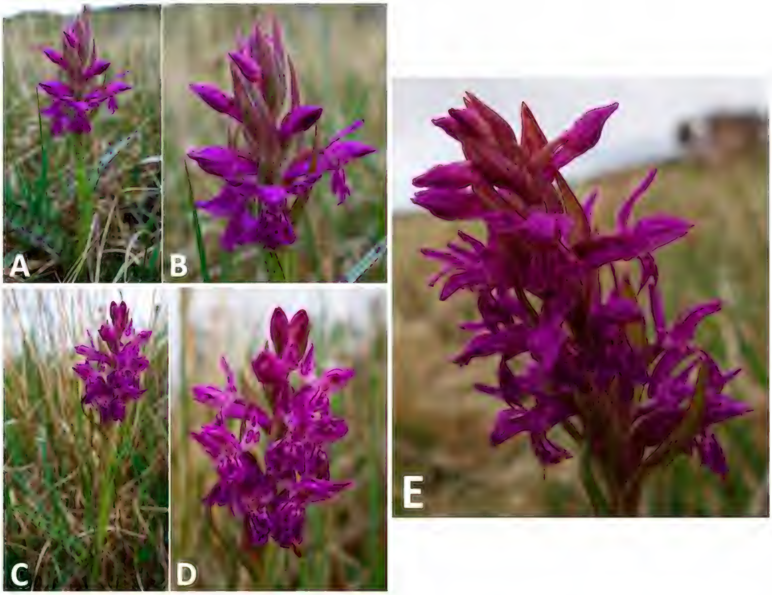

Fig. 2. Pugsley's marsh-orchid (*Dactylorhiza traunsteinerioides*), Mull of Kintyre, Argyll, Scotland, 4th June 2021. The flower spike shown in (E) is unusually large for the species but is still lopsided. The flowers in (A-D) are more typical in size and shape with the complex deep purple lines on the flower lips and sepal, and heavily marked leaves, evident in both. Note that (B,D) are enlargements of (A,C), respectively, to reveal flower detail. (Photos: C.J. McInerny)

At the site in Argyll the Pugsley's marsh-orchids grow at a location and habitat distinct from those of other *Dactylorhiza* orchids. They were on small south-west-facing slope *ca.* 5 m above a wet mire in an upland bog area at 230 m a.s.l. Few other *Dactylorhiza* orchids grow on the slope, but instead grow in large numbers on the mire below. However, later in the season, the same slope had a colony of heath fragrant-orchids. The slope is covered in grasses with much black bog-rush (*Schoenus nigricans*) present; black bog-rush is reported to be often associated with *D. traunsteinerioides* (Harrap & Harrap, 2009; Cole & Walker, 2020).

Pugsley's marsh-orchids are distinctive when compared with other *Dactylorhiza* orchids, with a combination of features identifying the taxon (Harrap & Harrap, 2009; Cole & Walker, 2020) (Figs. 1 and 2). These include: (1) the bracts and upper stem are strikingly infused with purple; (2) the flowers are a vivid purple colour with complex darker purple markings of bold loops and blotches on the lips and lateral sepals; (3) the flower shape is typically three-lobed, with the central lobe longer and narrower than the two side lobes; (4) the flower head is often lopsided, with more flowers on one side than the other; (5) the flower head has relatively small numbers of flowers, typically 6-14, more rarely up to 18; (6) there are just three to five leaves evenly spaced on the stem, which are narrow, with the second leaf usually the widest being up 12 mm across; (7) sometimes, as illustrated in Figs. 1 and 2, the bracts and upper surface of the lower leaves are boldly marked with purple spots, the purple extending along the outer margin of the leaf . The presence or absence of purple spotting on the leaves and bracts was previously used in Scotland to separate the then recognised *D. lapponica* from *D. traunsteineri* (Allan & Woods, 1993), but is now considered a variable character within *D. traunsteinerioides* (Cole & Walker, 2020).

The extremely rare flecked early marsh-orchid, *D. incarnata* ssp. *cruenta* has been recorded from similar habitats to those occupied by *D. traunsteinerioides* in western Ireland and Scotland, but is found at just two sites in Scotland in Wester Ross (Allan & Woods, 1993; Cole & Walker, 2020). This subspecies of *D. incarnata* shares purple infusion on the bracts with *D. traunsteinerioides*, but has bold spots on both sides of the leaves. It also flowers later in the season, typically mid-June.

It is likely that the Pugsley's marsh-orchid is more widespread in north-west Scotland but is overlooked and under-recorded. Much apparently suitable moor habitat is present across the region where black bog-rush, often associated with *D. traunsteinerioides*, can be common and widespread. It is hoped that this Short Note has highlighted the features required to identify the taxon, and that observers will be vigilant to any purple *Dactylorhiza* orchids growing in the region that flower in mid- and late May, and examine them to see if they might be Pugsley's marsh-orchid.

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Donacaula forficella (Lepidoptera: Crambidae): a moth new to Scotland

R.B. Weddle

89 Novar Drive, Glasgow G12 9SS

E-mail: richard@canto.plus.com

At Bowling Harbour, West Dunbartonshire on 3rd August 2018, Claire Martin of the Scottish Waterways Trust (now defunct) organised a Bioblitz. As part of the event, Alan Kerr ran moth traps the previous night in the Scottish Canals compound there, which attracted (in separate traps) single male and female specimens of *Donacaula forficella*. Their identification was confirmed by dissection of the genitalia by Mark Young, who added it as a new Scottish species to the unpublished List of Scottish Micro-moths which he maintains.

The moth was found again by Dean Stables beside the Glasgow branch of the canal at Ruchill, Glasgow on 1st July 2021, and was confirmed from the genitalia by Nigel Richards. Further specimens were found two days later by Alan Winthrop at an outside light in his garden, less than 100 m from the canal at Bishopbriggs, East Dunbartonshire (Fig. 1).

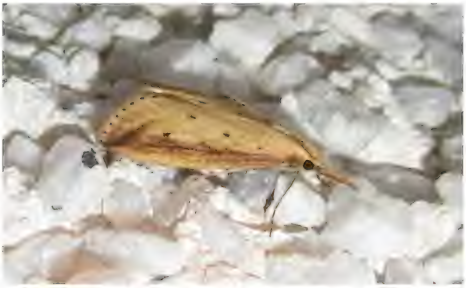

Fig. 1. *Donacaula forficella* female, forewing length 12 mm, Bishopbriggs, East Dunbartonshire, Scotland, 3rd July 2021. (Photo: Alan Winthrop)

Donacaula forficella (Thunberg, 1794) has been given the English name pale water-veneer, reflecting its preferred wetland habitat, where the caterpillars feed on the leaves of plants such as reeds and sedges. It is described as local in those parts of Great Britain and Ireland where it has been recorded (Sterling *et al.*, 2012). However, there were no previous records north of the southern parts of Lancashire and Yorkshire, England, though it has been recorded in Northern Ireland (NBN, 2021; Sterling *et al.*, 2012). The fact that the first records were beside the Forth and Clyde Canal towards its western end, and the subsequent records were adjacent to the same canal in Glasgow and Bishopbriggs, suggests that the moth could be spreading eastwards along the canal. It may well be found in more easterly sections of the canal in future years.

It should be remembered that, on NBN distribution maps, the absence of occurrences in an area does not necessarily confirm absence of the species. On the other hand, the prior absence of the moth from the Young List of Scottish Micro-moths confirms that the moth had not been previously reported as occurring in Scotland.

The moth has not so far been recorded at the Scottish Canals compound at Applecross Basin, Hamiltonhill, further towards the city centre on the Glasgow branch of the canal, though it may well appear there once the canal vegetation has recovered from the recent development work in that section.

The 2018 sightings fell within the Watsonian vice-county of Dunbartonshire (VC99) and the more recent records were in Lanarkshire (VC77).

I thank the recorders of the various sightings for sharing their information. Thanks also to Scottish Canals for allowing the use of their compound in Bowling, and to Alan Winthrop for the photograph shown in Fig. 1.

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Slender burnished brass moth *Thysanoplusia orichalcea* (Lepidoptera: Noctuidae) in Glasgow, Scotland

M.M. Butowska[1] & R.B. Weddle[2]

[1]2-1, 4 Balgair Terrace, Glasgow G32 0PF
[2]89 Novar Drive, Glasgow G12 9SS

[1]E-mail: mbutowska@yahoo.co.uk

On 5th July 2021, Ardiana Nela found a caterpillar on a basil plant (*Ocimum basilicum*) bought in a supermarket in Glasgow, Scotland. The larva (Fig. 1) was green, *ca.* 30 mm in length, with two pairs of prolegs, sparse setae, black eyes and true legs, and dark longitudinal markings on the thorax and abdomen. The caterpillar was left in the basil plant and on 6th July 2021 it created a cocoon, which was almost entirely wrapped in two leaves so that the pupa was not visible. This stage lasted 15 days and on 21st July the moth emerged (Fig. 2A). After the fully expanded moth was photographed (Fig. 2B,C) , it was released in an enclosed back garden of tenement flats in Kinning Park in Glasgow.

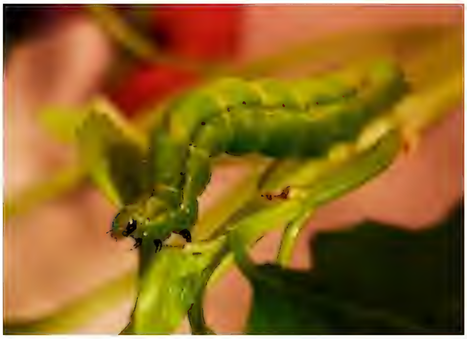

Fig. 1. Slender burnished brass moth (*Thysanoplusia orichalcea*) larva on 5th July 2021, Kinning Park, Glasgow, Scotland. Larva length *ca.* 30 mm.
(Photo: M. Butowska)

After the release, the photographs of the moth were compared with the image record from the Elgood Collection in Wisbech Fenland Museum (Wheeler, 2021). This led to the suspicion that the moth was a slender burnished brass (*Thysanoplusia orichalcea*), based on the colour and shape of the golden L-shaped area covering the central and subterminal regions of the wing. Images of the moth were submitted to Butterfly Conservation and then passed onto RBW in his capacity as moth recorder for Lanarkshire, and he confirmed the moth to be a slender burnished brass.

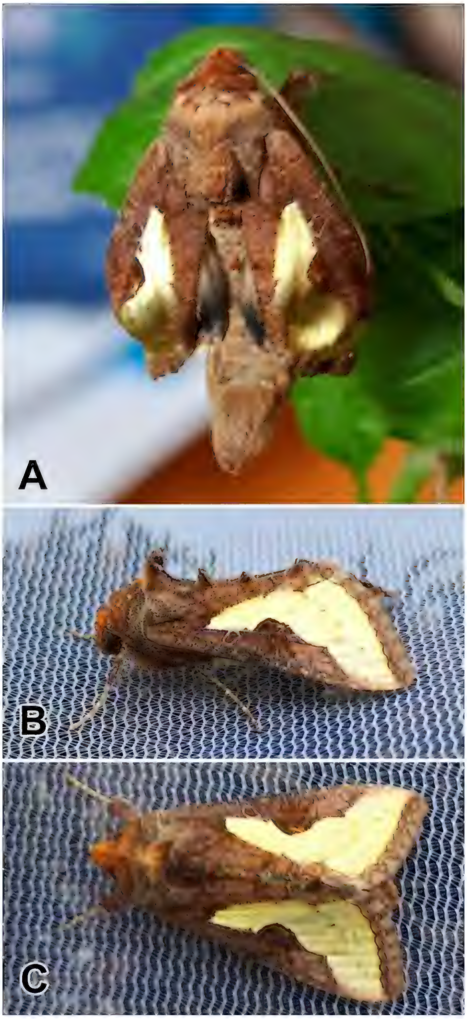

Fig. 2. Slender burnished brass moth (*Thysanoplusia orichalcea*) imago. Kinning Park, Glasgow, Scotland. (A) Shortly after emerging from the cocoon. (B) After the wings of the moth had fully expanded; side view. (C) After the wings had fully expanded; top view. Forewing length *ca.* 20 mm. (Photos: M. Butowska)

T. orichalcea (Fabricius, 1775) originated in Indonesia but is now widely distributed in the tropics and subtropics of the Old World, and has spread to Europe, Australia, and New Zealand. It is established in much of Africa and potentially around the Mediterranean and on Malta (Stringer *et al.*, 2008; Hill *et al.*, 1987; Waring & Townsend, 2017). In Britain, it is a rare adventive immigrant species, which has been seen fewer than 100 times (Waring & Townsend, 2017), mostly in south and south-west England (NBN, 2021). This is only the second confirmed sighting of the species in Scotland. The first was by L. Chilvers in July 2020, inside a house in Dunbar, East Lothian (M. Cubitt, pers. comm.). The NBN website (NBN, 2021) is currently showing an "unconfirmed" record of slender burnished brass at the National Trust for Scotland gardens at Poolewe in 2016. This has been found to be a data-entry error for burnished brass (*Diachrysia chrysitis*) and will be amended in due course (D. Watson, pers. comm.).

T. orichalcea is considered an agricultural pest (Stringer *et al.*, 2008) as it feeds on a wide range of agricultural plants, including soybean (*Glycine max*), mint family (Lamiaceae), and various *Brassica* spp. (Hill, 1987). Although the packaging of the basil plant had a "Grown in Britain" logo, the species has not been observed to overwinter successfully or breed in the climate of the U.K. (Waring & Townsend, 2017). Therefore, the Glasgow specimen has likely travelled on produce imported from overseas - potentially Spain as a common source of green vegetable imports to the U.K. The herbs may have then been grown on and packaged in the U.K., or the caterpillar may have moved onto the basil from other produce in transit. The moth was released by itself in an urban area of Glasgow, and therefore was unlikely to find a mate to breed. Nonetheless, sightings such as this are important as they show the ease with which non-native pest species, with a potential to become invasive, can be unintentionally transported and possibly cause economic damage to agriculture, if established.

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The stinkhorn *Phallus impudicus* and the dog stinkhorn *Mutinus caninus* from around the Glasgow area, Scotland

M. O'Reilly

Scottish Environment Protection Agency, Angus Smith Building, 6 Parklands Avenue, Eurocentral, Holytown, North Lanarkshire ML1 4WQ

E-mail: myles.oreilly@sepa.org.uk

Over the last ten years the Clyde & Argyll Fungus Group (CAFG) has carried out numerous fungus forays including many in and around the Glasgow area. Records from these forays are submitted to the Fungal Records Database of Britain and Ireland (FRDBI) and subsequently to the National Biodiversity Network database (NBN). Those from the Glasgow area are copied to the Glasgow Museums Biological Records Centre (GMBRC). Notes on some of the more interesting fungal finds around Glasgow have been published in recent issues of *The Glasgow Naturalist* (McInerny, 2019; O'Reilly, 2018, 2019, 2020; O'Reilly & Mitchell, 2019). This note adds to these in relation to the stinkhorn family, Phallaceae, an unusual group of gasteromycete fungi with two representatives known in the Glasgow area.

The common stinkhorn (*Phallus impudicus*) is very distinctive with its phallic shape and nauseous odour (Fig. 1). It initially appears as a white egg-shaped fruit body, about 5 cm in diameter, with cord-like mycelial rootlets from which a hollow spongy stem erupts and extends rapidly to around 15-20 cm in height. The stem is surmounted by a honeycombed cap covered in an olive-coloured glutinous spore mass with an unpleasant sewage smell (Watling, 1973; Pegler *et al.*, 1995; O'Reilly, 2011). The slimy spore mass is especially attractive to flies (Diptera) which consequently crawl all over it (Fig. 1) and subsequently disperse the spores.

The common stinkhorn occurs in soil in woodlands, parks and gardens, associated with both broad-leaved and coniferous trees. It usually appears singly, standing erect (hence its binomial Latin name) but occasionally occurs in small groups. It is fairly common and widely distributed in Scotland, though it seems to be absent from some of the western and northern islands (NBN, 2022). There is also an unusual variety (*P. impudicus* var. *togatus*) which sports a short lacy skirt below the head, but this is very rare with only a single Scottish record, near Loch Lubnaig, Perthshire in 1987 (NBN, 2022).

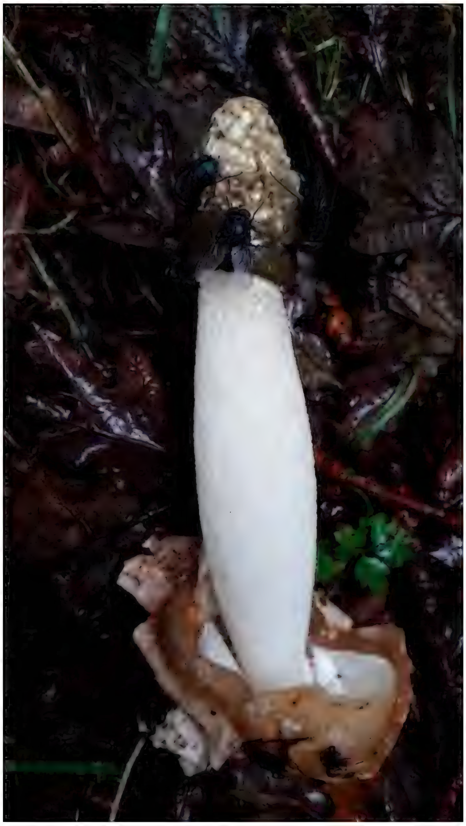

Fig. 1. An uprooted common stinkhorn (*Phallus impudicus*) with attendant blue bottle flies (*Calliphora vomitoria*). Rossdhu, Loch Lomond, Scotland, October 2021. (Photo: M. O'Reilly)

A survey of the fungi of Glasgow Parks was published just over 40 years ago (Marshall, 1979) and, although no stinkhorns were found during the survey, it was stated that common stinkhorns were known from the Pollok, Linn, and Dawsholm Parks. The author has unpublished records from around the same time in Pollok Park (North Wood) in September 1978 and August 1979. A detailed inventory of common stinkhorn records in and around Glasgow is now available from the GMBRC, and a summary of those since the year 2000 is provided in Table 1. It is evident that common stinkhorns are widespread throughout the area and still occur in Pollok, Linn, and Dawsholm Parks with records also in the country parks at Dams to Darnley, Cathkin Braes, Calderglen and Chatelherault. There are also recent findings in and around Glasgow at Garscube, Dalmarnock, Bothwell, Bishopton, Milngavie, Lennoxtown and further afield at Drymen, Helensburgh, and New Lanark.

Year	Area	Location	Grid Reference
2000	Neilston	Glanderston Wood	NS496565
2000	Old Kilpatrick	The Saltings	NS464727
2000	Uplawmoor	Uplawmoor Wood	NS439557
2000	Dumbarton	Whiteley Wood	NS383767
2006	Hamilton	Chatelherault CP	NS743530
2006	Glasgow	Dams to Darnley CP	NS522583
2007	Glasgow	Cathkin Braes CP	NS610585
2008	Hamilton	Chatelherault CP	NS7353
2008	Glasgow	Pollok CP	NS557619
2008	Glasgow	Pollok CP	NS553625
2008	Glasgow	Pollok CP	NS553622
2009	East Kilbride	Calderglen CP	NS6498652591
2009	Glasgow	Pollok CP	NS551618
2011	Glasgow	Linn Park	NS58465895
2013	Bothwell	Bothwell Castle Woodlands	NS68895956
2013	Drymen	Buchanan Estate	NS45858884
2013	East Kilbride	Calderglen CP	NS65045275
2013	Hamilton	Chatelherault CP	NS7353
2013	Helensburgh	Duchess Wood	NS28718384
2013	Bishopton	Formakin Estate	NS41077089
2013	Lennoxtown	Woodhead Estate	NS60967853
2013	Lennoxtown	Woodhead Estate	NS61217855
2014	Glasgow	Garscube Estate	NS553702
2015	Glasgow	Dawsholm Park	NS553696
2015	Glasgow	Clyde Walkway, Dalmarnock	NS6154662653
2017	New Lanark	Falls of Clyde SWT Reserve	NS8820540978
2018	New Lanark	Falls of Clyde SWT Reserve	NS88264075
2020	Milngavie	Dougalston	NS56627416

Table 1. Common stinkhorn (*Phallus impudicus*) records, 2000 to 2020, from the Glasgow Museums Biological Records Centre (GMBRC). CP, Country Park; SWT, Scottish Wildlife Trust.

The dog stinkhorn (*Mutinus caninus*) is similar to the common stinkhorn but is more slender and smaller, attaining a length of 10-12 cm (Figs. 2-4). The stem and especially the head have a pale orange-red colouration and the smell from the spore mass is said to be faint. It usually occurs in small groups with the stems at various angles and often drooping or prostrated. The dog stinkhorn occurs in similar habitats to the common stinkhorn and has a similar distribution throughout Scotland but is very much scarcer. The NBN Atlas shows only a few old records from around Glasgow: near Cumbernauld, Milngavie, and Hamilton (NBN Atlas, 2022). The GMBRC database also holds only a few records which are from other sites: Cardonald, Chatelherault, and Rouken Glen. There are also a couple of old records from Balloch and Paisley Glen on the FRDBI database along with more recent finds at Kilmahew Estate, Cardross in 2017 (Fig. 2) and at Cawder Wood, Bishopbriggs in 2018 (FRDBI, 2022). To these records can be added a further group of around a dozen found under conifers by Laura Allen at Chatelherault (NS742526) on 4th October 2020 (Fig. 3). These various dog stinkhorn records around Glasgow are summarised in Table 2.

The dog stinkhorns found by the author at Rouken Glen in October 2011 comprised a group of about 20 specimens under a large yew tree about 100 m north of the boating pond (Fig. 4A). A single specimen appeared at the same spot one year later, in October 2012, but no further specimens have been observed there since. The stems of the Rouken Glen specimens were a strong yellow colour with the tip, beneath the spore mass, being distinctly orange (Fig. 4B). The stems of the Kilmahew and Chatelherault specimens were a pale cream colour and the tips a deep orange with dark brown spore masses (Figs. 2 and 3).

While the presence of common stinkhorns can often be detected initially by their smell, finding dog stinkhorns is more challenging due to their fainter smell and smaller size, and so it is possible that many occurrences of the latter go unnoticed. Other types of stinkhorn should also be watched out for in Scotland. The sand stinkhorn (*P. hadriani*) occurs in sandy soils, including sand dunes and is known from just a handful of Scottish sites in eastern Scotland and near the Borders (NBN, 2022). It is very similar to the common stinkhorn but the “egg” develops a distinct pinkish hue and the spore mass initially smells of violets. It was one of the first recognisable fungal species described with the original account and illustration by the Dutch botanist Hadrianus Junius in 1564, from specimens found on sand-dunes in the Netherlands (see Ramsbottom, 1977). Ravenel’s red stinkhorn (*M. ravenelii*) is very similar to the dog stinkhorn but has a carmine red tip and a strong foetid smell. However, it appears to be very rare in the U.K. with the NBN Atlas showing only three U.K. locations: a couple near London and one near Manchester (NBN, 2022).

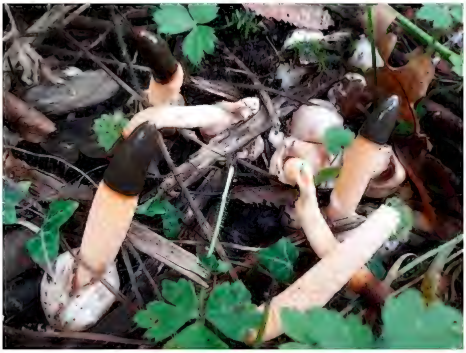

Fig. 2. A group of dog stinkhorns (*Mutinus caninus*). Kilmahew Estate, Cardross, Dunbartonshire, Scotland, October 2017. (Photo: M. O'Reilly)

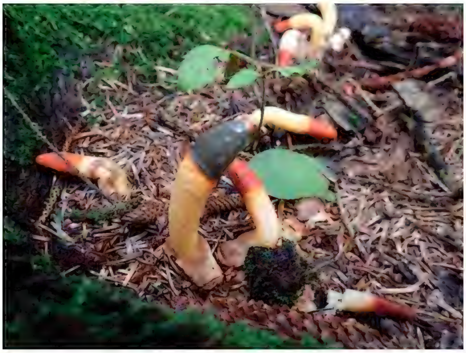

Fig. 3. A group of dog stinkhorns (*Mutinus caninus*). Chatelherault, Hamilton, Lanarkshire, Scotland, October 2020. (Photo: L. Allen)

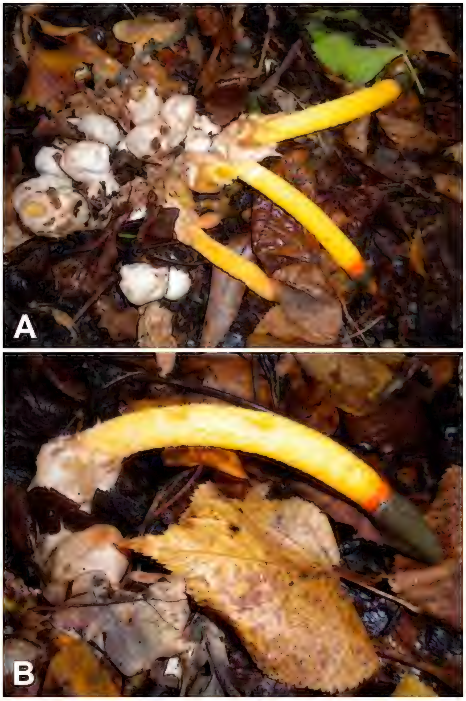

Fig. 4. Dog stinkhorns (*Mutinus caninus*). Rouken Glen, Glasgow, Scotland, October 2011. (A) Group. (B) Single specimen. (Photos: M. O'Reilly)

Year	Area	Location	Source
1876	Lanarkshire	Near what is now Cumbernauld	NBN Atlas
1900	Glasgow	Craigton Wood*	GMBRC
1901	Glasgow	Milngavie	NBN Atlas
1980	Loch Lomond	Balloch	FRDBI
1985	Paisley	Paisley Glen	FRDBI
2001	Hamilton	Baron's Haugh	NBN Atlas
2008	Hamilton	Chatelherault CP	GMBRC
2011	Glasgow	Rouken Glen	GMBRC
2012	Glasgow	Rouken Glen	MO'R
2017	Cardross	Kilmahew Estate	FRDBI
2018	Glasgow	Cawder Wood, Bishopbriggs	FRDBI
2020	Hamilton	Chatelherault CP	This Note

Table 2 – Dog stinkhorn (*Mutinus caninus*) records from around the Glasgow area. *This is now Cardonald Cemetery. CP, Country Park.

Other more exotic members of the Phallaceae are illustrated in Buczacki *et al*. (2012). The red cage fungus (*Clathrus ruber*) is considered as native to southern Europe, and possibly a rare native to Britain. It has been widely recorded in southern England and has also been found near Dunbar, East Lothian, in 1881, Kilmelford, Argyll, in 1917, and near Dundee in 1979 (Ramsbottom, 1977; NBN, 2022). Similarly, devil's fingers, or octopus stinkhorn, (*C. archeri*) a probable introduction from Australasia, has become widespread in southern England and Wales and also now occurs in the Isle of Man and Northern Ireland, so may well be found in Scotland. It has a 4 cm whitish fruit body with four to seven pink tentacle-like arching arms about 7 cm long (Fig. 5A,B).

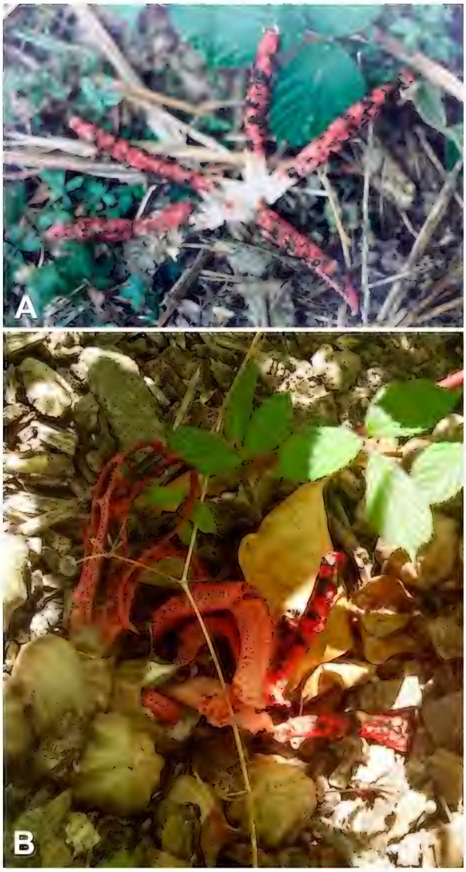

Fig. 5. Octopus stinkhorn (*Clathrus archeri*). (A) Uzerche, France, August 1980. (B) Groombridge, East Sussex, England, August 2020. (Photos: M. O'Reilly (A) & Tim Clark (B))

Thanks are due to Richard Weddle for providing GMBRC records, Dick Peebles for leading the CAFG forays, Laura Allen for providing the 2020 record and photos of dog stinkhorns from Chatelherault, and Tim Clark for the octopus stinkhorn photo from East Sussex.

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Adder swimming across Loch Lomond, Scotland

C.J. McInerny

School of Life Sciences, University of Glasgow,
Glasgow G12 8QQ

E-mail: chris.mcinerny@glasgow.ac.uk

The adder (*Vipera berus*) has a wide distribution across Scotland including some west coast islands where, in some areas, it can be reasonably common (McInerny & Minting, 2016). One such area is the shores of Loch Lomond where adders have been studied and monitored over a number of years (McInerny, 2014a,b, 2016, 2017, 2019).

Adders are normally territorial, moving relatively short distances from their winter underground hibernation holes, so-called hibernacula, which they can re-use in consecutive winters. Radio-tracking studies have shown that snakes, particularly males, can move a few km each year, searching for food and mating opportunities, before returning to their winter hibernation sites (Hand, 2019). During such movements they can cross many terrains, including burns and rivers, being adept swimmers, and have even been found on seashore strandlines (McPhail, 2011; McInerny & Minting, 2016).

In this context Stella Rice and Richard Fotheringham made an extraordinary observation of an adder swimming across Loch Lomond while kayaking (Fig. 1 and video which can be viewed at https://www.youtube.com/watch?v=Y8ka5IZ3KIc). The snake, likely a female, was observed at 12.50 p.m. on 2nd June 2021 at approximately NS3628895359, mid-loch between Ross Point and Culag, approximately 500 m from the east shore and 1 km from the west shore.

It is not clear from which side of Loch Lomond the adder originated, although large populations are known to be present on the east shore (McInerny, 2017), so this seems the more likely source. Adders are also present on some of the inches (islands) of Loch Lomond so, conceivably, it could have originated from one of these. Whatever its source, this highly unusual observation of a swimming adder in the middle of a large loch illustrates that they can cross sizeable bodies of water, potentially to find new feeding grounds, locate other snakes with which to mate, or even colonise new areas. Consistent with the latter it has been suggested that the aquatic proficiency of adders allowed the species to colonise many islands in the Baltic Sea where they are currently found, without the need for land-crossings (Carlsson & Tegelström, 2002; Ursenbacher *et al.*, 2006).

It would be intriguing to know if this individual was able to return to its home territory and hibernation site; perhaps the water crossing was intended and had been completed before. Either way this observation demonstrates that snakes can move large distances and cross significant bodies of water to reach new areas. It will be interesting to see if the publication of this Short Note results in the reporting of other similar observations elsewhere in Scotland.

I thank Stella Rice and Richard Fotheringham for sharing with me this fascinating observation and the use of their images in the Short Note.

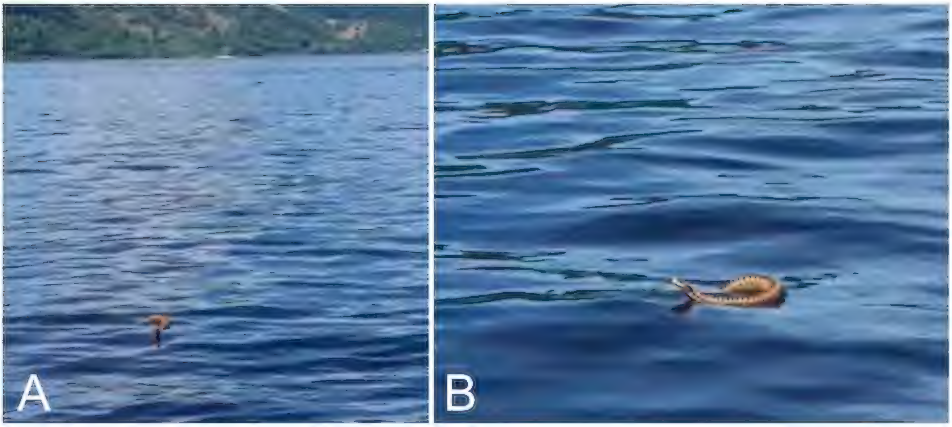

Fig. 1A,B. Adder (*Vipera berus*), likely a female, swimming across Loch Lomond, Scotland, between Ross Point and Culag, 2nd June 2021. The snake was mid-loch, approximately 500 m from the east shore and 1 km from the west shore. These two images are screen grabs from a video which can be viewed at https://www.youtube.com/watch?v=Y8ka5IZ3KIc. (Photos: Stella Rice and Richard Fotheringham)

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The leaf-beetle *Bruchidius villosus* (Coleoptera: Chrysomelidae): occurrences in Glasgow, Scotland

R.B. Weddle

89 Novar Drive, Glasgow G12 9SS

E-mail: richard@canto.plus.com

On a visit to a brownfield site beside the Forth and Clyde canal at Collina Street, Maryhill, Glasgow on 22nd May 2015, I swept a number of insects from broom flowers (*Cytisus scoparius*). I was surprised to find that the sample included three specimens of the leaf-beetle, *Bruchidius villosus* (Fabricius, 1792) (Fig. 1), which reference books state as being absent from Scotland, though it is widespread in central and southern England and Wales, local in Northern Ireland, and very local in northern England (see, e.g., Duff, 2016).

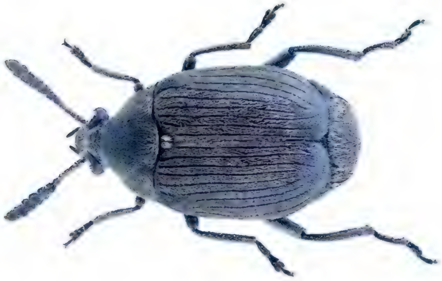

Fig 1. The leaf-beetle *Bruchidius villosus* collected from broom (*Cytisus scoparius*), Dietscha, Selbitz, Bavaria, Germany, 5th June 2020; size 3.3 mm. (Photo: U. Schmidt, https://creativecommons.org/licenses/by-sa/4.0/deed.en)

This distribution is borne out by the map on the National Biodiversity Network Atlas (NBN, 2021), which shows the nearest records to be in the north of Cumbria, England. In view of the possibility that there may be records which had not been submitted to NBN, I also enquired at the National Museum of Scotland, Edinburgh, the Hunterian Museum, Glasgow, and the Biological Record Centres which cover Dumfries and Galloway and the Borders, as the latter are the most likely areas in Scotland where the beetle would first appear if spreading northwards naturally. No Scottish sightings had been recorded.

I returned to the site a few days later and again found the beetle on different broom plants, a variety with pink-tinged flowers, whereas the original plant was the typical yellow-flowered form. It is possible that the plants with variegated flowers were garden escapes, though this colour-form does occur naturally. However, given the apparent abundance of this species in the Collina Street area, in contrast to its absence in the rest of Scotland, it is tempting to speculate that the insect was introduced on cultivated species in a nearby garden, though the these were not looked for.

A specimen was retained and will be donated to the Hunterian Museum.

I am grateful to Ashleigh Whiffin at National Museums Scotland, who also checked the Scottish Insect Records Index (SIRI), Geoff Hancock at the Hunterian Museum, Jackie Stewart at The Wildlife Information Centre (TWIC), and Mark Pollitt at South West Scotland Environmental Information Centre (SWSEIC) for checking their records for this species.

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First record of wild larvae of the short-necked oil beetle *Meloe brevicollis* Panzer (Meloidae) in Scotland

J.R. Silvey

RSPB Scotland, 2 Lochside View, Edinburgh
EH12 9DH

E-mail: james.silvey@rspb.org.uk

Oil beetles (Meloidae) are medium to large, 15-30 mm black beetles often found in open habitats, particularly those populated by solitary bees (Hymenoptera). Oil beetles in Scotland belonging to the genus *Meloe* are kleptoparasites of solitary bees. Scotland has just three species of oil beetle: the most frequently encountered violet oil beetle *Meloe violaces* Marsham, the possibly extinct (Ramsay, 2011) black oil beetle *M. proscarbeaus* Linnaeus, and the rare short-necked oil beetle *M. brevicollis* Panzer (Fig. 1).

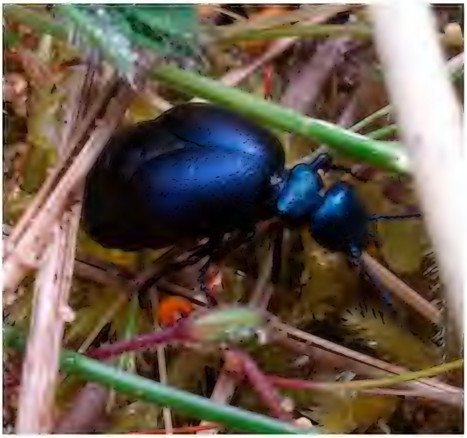

Fig. 1. An adult short-necked oil beetle (*Meloe brevicollis*), Crossapoll dunes, Isle of Coll, Scotland, 12th May 2014. The beetle is *ca.* 20 mm long. (Photo: Scott Shanks).

The short-necked oil beetle was presumed extinct in the U.K. until a population was discovered in Devon, England in 2006, followed by the first Scottish record on the Isle of Coll in 2009 (Redpath, 2010). Since then, other populations have been discovered including recently in Pembrokeshire, Wales in 2020 (Moran, 2020).

The discovery on Coll remained the only known Scottish population until 2021 when individuals were also recorded on Barra and Islay in similar habitats to those found on Coll. Despite several surveys, no oil beetles have been recorded on the neighbouring island of Tiree or Gunna (J. Bowler, pers. comm.). The first specimen on Coll was found in the Crossapoll dunes (Tràigh Chrossapol) and surveys throughout the island in 2014 confirmed that the species could be found wherever dune habitats were in suitable condition. From the beetle's first discovery on the island it was predicted that the host for the species would be the nationally rare northern colletes solitary bee (*Colletes floralis*), as the two species were associated with the same habitat. This was confirmed in 2017 when excavations of previously marked bee nests found two short-necked oil beetle larvae feeding on the nest provisions of northern colletes (Silvey, 2017).

Previous *ex situ* work on the species had shown that females begin to lay their eggs around ten days after emergence, and that eggs hatched after 37 days when incubated at 20°C (J.R. Silvey, pers. obs.). This time period further confirmed northern colletes as the preferred host, as larvae timed their emergence to coincide with the main flight period of the host species, rather than the later emerging heather colletes (*Colletes succinctus*), which is also present on the island.

With the host confirmed, efforts were made in 2019 to record the free living triungulins (the larval stage that attaches to a bee and so gains access to the nest), which had not been recorded in Scotland before. Using the emergence time of captive larvae in 2016 and the known emergence time of northern colletes, fieldwork began on the dunes of Coll on the 27th June 2019.

The survey method for larvae initially involved ten-minute searches in areas where adult beetles had been previously found. The behaviour of triungulins was expected to be similar to that of other oil beetle species and searches were therefore focussed on flowers with a careful search for the small (*ca.* 1 mm long) larvae (Fig. 2). It soon became apparent that larvae were adept at hiding deep within the sepals of the flowers but any slight movement of the flower with a pencil or finger would cause them to scurry into the open presumably because they associate the vibrations with the possible presence of a host species. Using this technique, the first triungulin was found on hawkbit (*Leontodon* sp.) with 23 larvae found in total across the dune site. Larvae were confirmed as *M. brevicollis* using Walters (2011).

Larvae were found on a wide range of plant species (Table 1) but not recorded on any flowering grass heads such as marram (*Ammophila arenaria*), potentially indicating a preference for the species of plants that bees were likely to visit.

Given the time of year and habitat type, the majority of flowers present in the area were yellow and as such the dark brown triungulins were extremely conspicuous on the petals of these flowers when disturbed (Fig. 2).

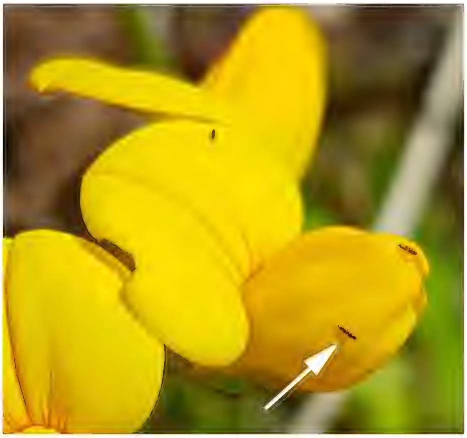

Fig. 2. Three triungulins (one indicated by arrow) on birdsfoot-trefoil (*Lotus corniculatus*), Isle of Coll, Scotland, 2019. (Photo: J.R. Silvey)

Species	**Number of larvae**
Hawkbit *(Leontodon* sp.*)*	5
Birdsfoot-trefoil (*Lotus corniculatus)*	6
Buttercup (*Ranunculus* sp.*)*	2
Kidney vetch (*Anthyllis vulneraria)*	5

Table 1. Number of triungulin larvae found on different species of flower, Isle of Coll, Scotland, 2019.

This greatly aided survey efforts and further triungulins were found adjacent to active bee colonies in another area of the island. It is theorised that the hiding behaviour exhibited by triungulins is in response to a potential avoidance behaviour displayed by the target bees whereby they actively avoid flowers on which triungulins are visible. It would have been interesting to document the interactions between bees and triungulins. However, no visits by bees to occupied flowers were witnessed in 2019, and all bees caught and examined lacked visible triungulins.

This discovery represents the first recording of the triungulin larvae of short-necked oil beetles in the wild in Scotland.

The author would like to thank the RSPB Scotland reserve staff on Coll for their support with this work, and all of the friends and volunteers who assisted with survey efforts over the years.

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https://doi.org/10.37208/tgn27417

A spiny-headed worm, *Plagiorhynchus cylindraceus* (Acanthocephala), in hedgehog faeces in southwest Scotland

E.G. Hancock

Hunterian Museum, University of Glasgow, Glasgow G12 8QQ

E-mail: geoff.hancock@glasgow.ac.uk

While examining faeces of hedgehog (*Erinaceus europaeus* (L.)) from a garden in Kirkcudbright, Dumfries and Galloway, Scotland (NX675486) on 26th July 2020, the author found a small white worm-like organism. To the naked eye it seemed it might be an fly (Diptera) larva but closer examination quickly revealed a spiny- or thorny-headed worm, phylum Acanthocephala (Fig. 1). This prompted an investigation into its identity and an attempt to understand the possible circumstances leading to its occurrence. The diet of a hedgehog can sometimes be revealed from fragments of material if they can be identified in their faeces but an entire food item would not normally be found undamaged after mastication, ingestion and digestion. The good condition of the specimen can be attributed to acanthocephalans being internal parasites usually within the lower alimentary canal of their hosts.

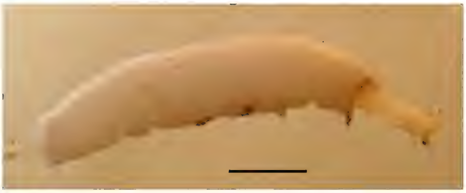

Fig. 1. *Plagiorhynchus cylindraceus*. Whole animal, 4.1 mm long, from hedgehog faeces in Kirkcudbright, Scotland, July 2020. Hunterian Museum, Acc. No. 167076. The proboscis is in the right. Scalebar: 1 mm. (Photo: E.G. Hancock)

The example from Kirkcudbright can be identified as a member of the family Plagiorhynchidae based on the host species and external morphological characters, and using the key by Amin (1987). Being 4.1 mm in length, including the proboscis, it is typical of acanthocephalan adults in terms of size. The widespread species *Plagiorhynchus cylindraceus* (Goeze, 1782) has been recorded from European hedgehogs in western Europe (Pfäffle, 2015; Skuballa, *et al*., 2010). The proboscis of the Kirkcudbright specimen (Figs. 1 and 2) closely resembles that illustrated in Garcia-Salguero *et al.* (2019) and Lisitsyna (2019) as in Fig. 3. Absolute certainty on identification would require clearing to reveal internal organs, which has not been attempted. The specimen has been added to the collection of the Hunterian Museum, Glasgow, accession number GLAHM: 167076.

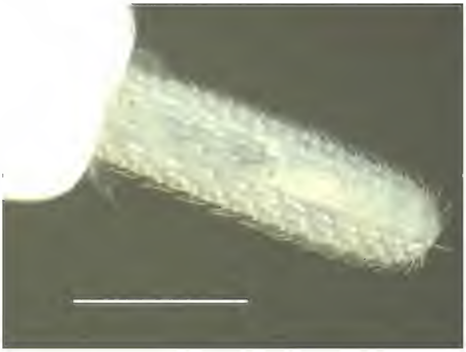

Fig. 2. Proboscis of *Plagiorhynchus cylindraceus* from Kirkcudbright, July 2020. Scalebar: 0.5 mm. (Photo: E.G. Hancock)

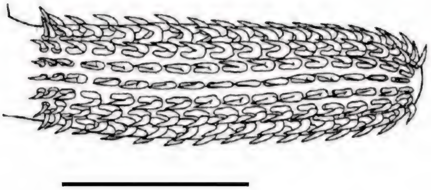

Fig. 3. Proboscis of *Plagiorhynchus cylindraceus*. Adapted from Lisitsyna (2019). Scalebar: 0.5 mm.

There are two parts to the life cycle of the majority of spiny-headed worms. Male and female adults mature within the definitive host, a vertebrate animal, and, after mating, eggs are released and pass out through the gut in the host's faeces. When these are consumed by an intermediate invertebrate host they proceed to grow in a series of stages. If an infested invertebrate is eaten by a subsequent vertebrate host, this dual life cycle can be completed. Spiny-headed worms are divided into three classes. The Archiacanthocephala use terrestrial mammals and birds as definitive hosts, whereas the Eoacanthocephala have aquatic hosts, which can be fish, reptiles or amphibians, and can occur in both freshwater and marine environments. Representatives of the third class, Palaeacanthocephala (to which the Plagiorhynchidae belong) can be found in vertebrates in all the above groups and their habitats. In aquatic systems, parasitisation occurs after consuming infected crustaceans. Terrestrial mammals and birds acquire them from eating woodlice, millipedes, centipedes or insects such as cockroaches (Morris & Crompton, 1982). With a substantially insectivorous diet, hedgehogs would seem to be susceptible to acanthocephalans finding a home in their gut.

An investigation by Skuballa *et al.* (2010) sampled hedgehogs post-mortem from casualties in animal rescue centres. From the U.K. portion of this study nearly half the sample size of 21 had spiny-headed worms. Some of these were found inside the alimentary canal, in which case the worms could be passed out of the body whole. Others were located within the peritoneal cavity where they remain trapped and can cause ulceration damage to the area by cyst formation and subsequent infection. This induces general weakness and loss of condition, and is believed to be a factor in the demise of young hedgehogs (Skuballa *et al*., 2010). The latter authors acknowledged that animals in poor health are likely to be over-represented in animal hospitals and that in the wild the level of infestation would be much less. The true hosts for the adult *P. cylindraceus* are passerine birds, frequently starling (*Sturnus vulgaris*) and blackbird (*Turdus merula*).

When a cystacanth, the infective stage, is ingested by a mammal such as a hedgehog rather than a bird, they can develop to adulthood but are said to be unable to reproduce (Pfäffle, 2015). However, Skuballa *et al.* (2010) suggested that hedgehogs may act as paratenic or transport hosts. This is a third strategy for spiny-headed worms by which a different species of vertebrate host that has become infected is then consumed by the definitive one. For this to apply to hedgehogs, they conjecture that a bird might consume the infected part of a road-killed hedgehog, for example, and could, theoretically at least, acquire the parasite by this intermediate process. *P. cylindraceus* has been recorded from predatory birds and crows on occasion. A comprehensive account of acanthocephalan biology is provided by Nickol (1985).

This Kirkcudbright observation is thought worthy of comment as, apart from the work of Skuballa *et al.* (2010), which mentions animal hospitals in Jersey and Wiltshire, few references have been found for the occurrence or distribution of *P. cylindraceus* in the U.K. James (1954) described examples of spiny-headed worms, identified as *Echinorhynchus rosai* Porta, 1910, from three specimens encysted in the liver and mesentery of a hedgehog. This name is now regarded as a synonym of *P. cylindraceus* (Golvan, 1956). There are specimens (labelled as *E. rosai*) accessioned in 1926 into the Natural History Museum, London collection from Vandelbury, Cambridgeshire, England.

Intermediate hosts *Armadillidium vulgare* (Latreille, 1804), the common pill woodlouse, and *Porcellio scaber* Latreille, 1804, the common rough woodlouse, both occur in the Kirkcudbright garden. In a natural history context, finding this example by examining faeces is serendipitous and not a feasible methodology for finding more. To have any expectation of success for recording hedgehog endoparasites, an investigation would have to be conducted by dissecting fresh road casualties or carcases obtained from deaths in animal sanctuaries. Some broader studies on internal parasites of hedgehogs have revealed much information on helminths (a general term for internal "worms" from different phyla such as tape-worms (phylum Platyhelminthes, class Cestoda), flukes (phylum Platyhelminthes, class Trematoda) and round-worms (phylum Nematoda)), though these lack information on spiny-headed worms (e.g. Boag & Fowler, 1988, and references therein). This paucity of records of Acanthocephala generally and an apparent complete lack of mention of this entire phylum on naturalists' internet recording sites or as part of any mapping schemes is probably because such a pursuit is beyond the inclinations of most wildlife enthusiasts.

Dr Omar Amin of Arizona, U.S.A., kindly responded to my query about identification and sent copies of some relevant papers. Dr Matthew Wayland, University of Cambridge, suggested in his valuable review the inclusion of more background information on the biology of spiny-headed worms. Dr Peter Olsen (Natural History Museum, London) very kindly spent some time searching for and finding specimens. Dr Fiona Ware (National Museums Scotland) and Jennifer Gallichan (National Museum of Wales) are also thanked but could find no relevant specimens of acanthocephalans in those collections.

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The Glasgow Naturalist (2022) Volume 27, Part 4, 86-93

BOOK REVIEWS

The Inside Out of Flies

Erica McAlister
Natural History Museum, London, 2020. 256 pages, hardback with numerous colour photographs, line drawings and graphics. ISBN 9780565094898.
£14.99

This is a most interesting book containing a vast number of facts presented in a broadly popular science manner. It follows the author's earlier prize-winning *The Secret Life of Flies*, also produced by the Natural History Museum, London. It continues her mission to inform readers of the extraordinary variety of form, life-style and diversity of the Diptera. Compared with more familiar insects, they have not only received less attention but suffer also from a negative profile, varying from being a bit of a nuisance to carriers of many of the world's deadliest diseases. This is balanced by their useful roles as pollinators and miniature waste disposal units. The vast majority of fly species, of which there are currently estimated to be 160,000, are neither good nor bad from an anthropocentric perspective. They can all provide information to ponder or simply admire.

The main chapters are devoted to a separate body part - heads, legs, wings, abdomens, antennae, etc., in a kind of entomological beauty contest. There is indeed considerable attractiveness and an occasional element of weirdness in the images chosen. The author explains that all the structures result from evolutionary processes, the products of selective pressures, and each has a purpose. They can be explained in terms of their functional morphology and witnessed by observing behaviour in the living insect. A welcome frankness is provided by admissions to not knowing why some are the way they are, awaiting future investigation.

This might make the book seem rather earnest but it is written in a light accessible style. To deal with the scientific background to the various chapters, the sources are not given in an academic manner. A name check and date for the latest research in the text can sometimes (though not always) be found in the reading list at the end. The interesting work on the appearance of flies' wings under ultraviolet light on p. 185 is not credited to the researchers in the text or caption, although the reference can be found hidden in the picture credits on the last page of the book. But, it's better to just read the text and not worry about who first discovered all the various phenomena.

There is a considerable sprinkling of errors, not all typographical. These show signs of hasty work by a copy editor and perhaps having to meet the annual publishers' deadline for the Christmas market was a factor. For example, the nice photograph of the piercing mouthparts of the stable fly, p. 114, has its caption copied into that of the more typical muscid spongy apparatus, p. 132. The photograph of eggs of a blowfly on p. 20 is labelled "maggots". Slightly confusing is a paragraph, p. 273, on the enlarged antennae seen only in males in some species (and so explained as sexual dimorphism linked to mating behaviour) repeated verbatim, p. 274, following a statement on its occurrence in both sexes in a few other flies, which is not so explicable. The caption for the house fly (*Musca domestica*) painting on p. 7 contains a word that does not exist, "*labiisl*", supposedly quoted from its description by Linnaeus in 1758. This is an example of using a mistranscribed text from the internet, something modern authors need to be wary of. The original source has "*labiis*", a word that does exist in Latin and the quote is actually for the genus *Musca*, not the species *M. domestica*. Later, p. 10, Linnaeus is credited with introducing mouthparts into his higher classificatory divisions but in fact it was his star pupil Fabricius who did this, enthusiastically developing his master's great work.

This reviewer has a long-standing interest in Diptera and, despite trying, could not "unlearn" sufficiently to be able to judge how successful the book might be in encouraging an interest in flies. There are no fly larvae with thoracic legs, unlike beetles in which some groups do and some do not, so as when and how did this defining characteristic of Diptera arise in evolutionary history? The book does not mention this absence of feature in such terms. The commonly held view can be queried (p. 192) that cranefly legs are deciduous (= autotomous) and so have an escape mechanism akin to lizards shedding their tails. There is no doubt that craneflies lose legs, accidents do happen, and they are often seen flying about with fewer than six. Some research has shown that they cannot readily release themselves when a leg is trapped (Nentwig, 1982). The ramifications of this cannot be pursued here and claims that craneflies have an evolved weakness in the base of the legs to allow them to escape, if it is actually true, would have to be reconciled with real-life observations.

The publisher's blurb "At every juncture she uncovers unique and surprising science lessons encapsulated in the form and function of the humble fly" is readily endorsed by this reviewer. In writing *The Inside Out of Flies* Erica McAlister will encourage more naturalists to engage with these insects. As well as setting out science lessons to be absorbed, she poses questions that seek answers. Following the previous title, *The Secret Life of Flies,* this book should be successful and is recommended for adding to the naturalist's library.

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E. Geoffrey Hancock

Entangled Life

Merlin Sheldrake

The Bodley Head, London, 2020. 358 pages, hardback with colour illustrations and line drawings. ISBN 9781847925190.
£20.00

Entangled Life is an extraordinary book with an ambitious remit to explain "How Fungi make our worlds, change our minds, and shape our futures". It examines and illustrates the role of fungi at many levels, e.g. mutualism with algae as in lichens; symbiosis, past and present with plants in the ecosystem; interactions with the animal kingdom, including humans. Although there is much detailed and up to date scientific information, it is written with a touch that is light, anecdotal and almost journalistic. This, surely, must widen the readership and, indeed, the book appears to have been selling out! For the more academic reader, there are 100 pages of notes, bibliography and index, allowing a follow-up of points of special interest. This allows the main text to flow well within each story line.

The author, although only 33 at the time of publication (2020), is well equipped to take us on this journey. He has a Ph.D. in tropical ecology from Cambridge which followed a pre-doctorate in ecological studies in Panama at the Smithsonian Institution, U.S.A. This allowed him to interact with an older generation of mycologists and fungal ecologists to whom he gives due respect in the text.

The introductory chapter, almost a book in itself, fills out background information about life-styles and life-cycles of fungi, particularly ectotrophic mycorrhizal fungi. The symbiosis of fungi and algae in lichens, the interaction of fungal hyphae and mycelial networks with plant roots in the soil, and the amazing battery of biochemical ability possessed by fungi are all examined. Subsequent chapters fill out on these topics.

The first of these examines the "lure" of fungi. Fungi produce smells. These interact with the rest of the biological world from bacteria to plant roots, nematodes, and the noses of vertebrates. The mutual and detrimental aspects of these relationships are examined along with detail of mycelial growth. Illustrations are delightfully made throughout with ink made from *Coprinus* toadstools. These concepts are followed up in "living labyrinths". Do fungi figure things out? This looks at the pathways and networks of fungal hyphae, and their interactions with the environment and each other. Examining the properties of the transfer of substances is difficult but the author reveals some extraordinary results confirming the extent and complexity of fungal networks. "The Intimacy of Strangers" follows on from this, taking an in-depth look at everything to do with lichens. Recent research is detailed and quite fascinating. Lichens are little complex biospheres with survival and ecological properties to astonish. Horizontal DNA acquisition is looked at here.

We move on to rather a quirky chapter "Mycelial Minds". Quite a number of fungi produce psilocybin and related compounds. The effects of one of these, LSD, on the human mind is examined, but we are grounded again by fascinating facts, this time, relating to the fungus *Ophiocordyceps unilateralis*, which reacts with carpenter ants. Other examples are given including a fungus which uses a virus to infect insects and renders them a consumable host to the fungus. The historic use of "magic mushrooms" is traced, although the conclusion is that the insect interaction is the likely evolutionary winner from a fungal perspective.

The next two chapters were my personal favourites. The first, "Before Roots", traces the progression of plant life from water to dry land. The interactions between green algae, photosynthetic bacteria and fungi appear to have made the colonisation of land possible. Lichens are one type of interaction, but 90% of land plants have a symbiotic association with fungi. The trading balance between fungi supplying water plus minerals and land plants supplying carbon plus lipids is discussed in terms of geological timescales and the perspective of carbon dioxide levels in the ocean and atmosphere. Trees seem to be one of the evolutionary outcomes made possible by mycorrhizal relationships. The results of modern radioactive tracing and DNA analysis are discussed and the knock-on effects for agriculture, horticulture and forestry are examined. This follows on to "Wood Wide Webs", a title from a phrase coined as understanding of the connectivity within the forest and woodland habitats began to be appreciated. Non-photosynthetic plants are described and their connections via mycorrhizal fungi to green plants. The general connectivity within the soil is far from simple. The role of viruses, bacteria, fungal networks and roots is discussed in terms of multiple connections, flow rates and general balance – all unseen by the overground observer. Lab experiments can be done, but who gains what in woodland ecology? This is seriously tricky to assess. Dr Sheldrake gives full credit to those grappling with these issues and gives a good analysis of experimental process and progress.

We now look at rotters in "Radical Mycology". We are informed that trees represent 60% of living biomass. Lignin is a tough, complex material and fungi, mainly white rotters, are the main recycling force. The biochemical adaptabilities of fungi are prodigious; cigarette butts, TNT, oil spillages - you name it, fungi can rot it. This may be the answer to breaking down plastics. Indeed, we are informed that fungal mycelia may also replace plastic. Companies in the U.S.A. are making all sorts products with mycelium from common wood-rotting fungi such as turkey tail. The next chair you buy from Ikea might be made from mycelium and packaged with mycelium. The future may be fungus, treated, of course. It wouldn't do to be picking oyster fungus off the table leg.

There are several topics in this book that I haven't detailed, for example home brewing and DNA stirring up fungal taxonomy. These are looked at again in the final chapters, "Making sense of Fungi" and "Epilogue". In addition, these chapters examine cultural attitudes to fungi and are substantially philosophical and reflective in content.

There is so much information in *Entangled Life*. It is true to its title. Life on earth is truly entangled. Reading this book meant a lot to me. My own Ph.D., a lifetime ago, was on mycology - fungal volatiles. This made me fully appreciate what an excellent collation and synthesis of old and new material Merlin Sheldrake has accomplished. It has been hard to locate recent research gathered in such an encompassing fashion. I feel it does, however, cater for a wide readership, not just a fungiphile like me. Not an easy achievement. It is assuredly a most thought- provoking and educative book and, yes, I just had to have my own copy to reread and follow up on all these innovative ideas.

Alison Moss

What is a Bird? An exploration of Anatomy, Physiology, Behaviour and Ecology

Tony D. Williams (Editor)
Princeton University Press, 2020. 368 pages, hardback with colour illustrations. ISBN 9780691200163.
£30.00.

My old professor used to say that defining a mammal was easy – "they're warm, they're hairy and they smell"- but defining a bird was more difficult. Flying and laying eggs obviously cover far too many other creatures; even having feathers seems no longer exclusive. Only a number of traits in combination will answer the question posed by the title, so the value of this large format, profusely-illustrated volume - part coffee-table book and part encyclopaedia - really lies with the subtitle.

Six authors from the U.S.A. and Canada have contributed 10 chapters. The first is a general overview of birds and bird biology by the editor; it forms a brief trailer to the topics that will be covered in more depth within the book and also includes some evolution and taxonomy. The second is devoted largely to feathers but with a nod to the unfeathered parts of the bird such as the beak, claws and bare skin. Feather types and distribution are covered, as well as the function of feathers in flight and display; there is considerable attention paid to feather colouring, including how factors such as sunlight can radically change a bird's appearance, and how different colours predominate in (e.g.) birds using the jungle floor as opposed to those in the canopy. Cleaning, moulting and replacement are briefly reviewed. Chapter 3 is devoted to bones, muscle and brain. Coverage of the skeleton is rather short and the reader might well ask if bones are modified for different life-styles (the size of the sternum in relation to the degree of aerial habit; the skull and the concussive effects of woodpecker-ing). Muscles are restricted to the flight muscles and the muscles of the syrinx, while the section on the brain chiefly deals with special senses with some space given over to sex and seasonal differences in the brain. Chapter 4 (entitled "Physiology") is a rapid grand tour of other body systems including the urinary, respiratory, circulatory, immune, alimentary, excretory and endocrine systems.

The next five chapters depart from the "structure and function" theme and deal with various key behaviours and ecology. Chapter 5 ("Getting around") deals with the mechanics of flight and the required high rate of metabolism, as well as flightlessness and swimming. It also touches on behaviours such as flocking, formation flying, flight displays and sleeping. Some of this is expanded in Chapter 6 "(Migration and Navigation") which looks at migration patterns, the cues that migrants use and the physiological demands and risks of migration; it ends with some often-neglected behaviours such as prospecting, dispersal and irruptions. Chapter 7 ("Food and Foraging") deals with the wide range of bird diets, including insects, fish, carrion, fruit and nectar through to blood, leaves and mineral-rich soil. It also considers how birds find their food source, including smell and echolocation, and behavioural issues such as piracy, tool use and hoarding. Chapter 8 ("Social behaviour and communication") deals with mating systems, social dynamics, birdsong and problem solving. Chapter 9 ("Reproduction") covers a wide range of topics including seasonality and cycles, territoriality, nesting, eggs, incubation and parental care.

Finally, Chapter 10 ("Human dimensions") contains many diverse topics, such as birds in myth, symbolism, art and fashion - at the Feather Market in Port Elizabeth, South Africa, I once learned that ostrich-feather adornments for ladies went out of fashion because the motor car had less headroom than the carriage. Birds not only inspire the technology of flying machines, but also walking robots and bullet trains. We hunt birds and they hunt for us; they give us diseases and we render some of them extinct.

Because of the multi-author approach, information sometimes spans several parts of the book and should perhaps have been gathered together by the editor. There are many examples of this. There is a description of the superb hearing skills of owls on p. 109, but you have to wait until pp. 224 or 249 to discover why. In fact, the most successful nocturnal owls have asymmetric ears (one is placed higher than the other, and the skull is lop-sided when viewed from in front) so that they can detect a sound source in the vertical plane, as well as the more normal horizontal one; we do the same by "cocking our head". In Chapter 3 (pp. 122-123) there is a section on the hippocampus and spatial memory, but the practical application of this - "now, where did I hide that nut?" - is dealt with on p. 197 and again on pp. 246-247.

In a similar vein, I feel that ideas that would interest the reader are omitted (perhaps because the different authors assumed they were dealt with elsewhere) and I sometimes felt that an extra sentence or two was needed. For example, there are two pages given over to the structure and function of the bird alimentary system in Chapter 4 ("Physiology"), whilst there is a whole chapter on diet (Chapter 7 – "Food and Foraging"). In the latter we learn that the red knot (*Calidris canutus*) changes its diet markedly during the year, but we never discover that the size of the knot stomach doubles between summer (when the birds eat easily digestible arthropods on the tundra) and winter (when they eat less digestible bivalves and gastropods in northwest European waters such as the Wadden Sea); researchers from Texel have shown that changes in stomach size can occur in less than a week to keep pace with migratory movements. Indeed, there is no discussion of whether gut morphology differs according to diet, though this is a considerable biological theme. It is interesting to know that the eggs of parasitic cuckoos have thicker shells than the eggs of their unfortunate hosts, but R.B. Payne (no relation) would doubtless make the more important point that, while non-parasitic cuckoos lay large, round eggs, parasitic cuckoos of the same body size have evolved to lay small, oval-shaped eggs more in keeping with the species they are targeting. I found one misidentification; the beautiful double spread photo on pp. 142-143 is captioned as "European bee-eaters" (*Merops apiaster*) but the birds are actually a group of little bee-eaters (*M. pusillus*).

If I have made something of a meal of the last two paragraphs, it is mainly because it defines where the book sits in the spectrum of bird literature. This is a book which would suit those readers who want to journey beyond the usual identification guides that dominate the market. It is quite different. On the other hand, it is too broad-ranging to be a specialist text-book, though I found that, if I wrote down a list of topics I would expect to see, many of them appeared in some form or another. What it does do (or did for me, anyway) is to act as a stimulus to hit the search engines for any topic I wanted to know more about. Is this the definition of a "primer" these days? If so, this book is a good one. It is accessible and well-written throughout and contains magnificent photos and diagrams. If you are interested in birds, want to learn more about their general biology, and have a robust book shelf, you should seriously consider it.

Tony Payne

Florapedia: A Brief Compendium of Floral Lore

Carol Gracie
Princeton University Press, 2021. 201pages, hardback with numerous line drawings. ISBN 069121140X.
£9.99

This neat pocket-sized book, full of fascinating information, would make an ideal Christmas present for those friends who enjoy digging the garden or watching gardening shows, walking in the countryside, or visiting the Chelsea Flower Show, in fact everyone on your Christmas list.

Carol Gracie calls *Florapedia* "A Brief Compendium of Floral Lore". The simple dictionary definition of "lore" is "knowledge and stories" so this title captures the essence of the book but is only half the story. The stories are delightfully varied in every way, from the sublime to the everyday, and illustrate the author's extensive research and field-work as a botanist. There are entries on plants, insects, trees, artists, explorers, gardeners, emperors (Napoleon) and more.

In fact, *Florapedia* is a very difficult book to categorise, given the diversity of its range and the scholarship of its entries, but apart from being arranged alphabetically, its organisation is totally random. Whether reading linearly or not, the reader finds themself inadvertently dipping in and out, and reaching for Google's help to follow through an intriguing snippet.

Carol Gracie has worked as an educationalist for over 30 years at the New York Botanic Gardens, and she has published a number of field guides, including a seminal work on the spring wild flowers of North East America. Gracie's experience is based in the Americas, north and south, but most of the information is universal and there is plenty here for the European reader. And it is likely the book will stimulate the British reader to think up their own examples.

Some entries link the two continents, for example, the father and son horticulturalists, John and William Bartram. John became George III's botanist for the American colonies, and his own garden in Philadelphia became a "mecca for visiting botanists from both the colonies and Europe." This garden was taken over by the state of Philadelphia in 1891, making it the oldest botanical garden in the U.S.A. John discovered a tree species, which his son later named *Franklinia alatamaha* (Theaceae) after his father's good friend, Benjamin Franklin. Extinct in the wild since the early 19th century, all later specimens have grown from seeds collected by William.

Gracie contends that, because they do not move, plants have had to evolve more imaginative means of reproduction. Take, for example, the blood root poppy (*Sanguinaria canadensis*, Papaveraceae). To preserve their pollen, the flowers only open when it is sunny, i.e. when its pollinators are around. A single leaf wraps itself protectively round the flower stalk but after pollination the leaves become attractive ground cover, and ants disperse the ripened seeds. Another example she includes is the corpse flower (*Amorphophallus titanum*, Araceae) which many Scots held their nose to see when it flowered in the Royal Edinburgh Botanic Garden in 2019.

The common and scientific names "Dutchman's breeches" and *Dicentra cucullaria* (Papaveraceae) are descriptive of the flowers, writes Gracie of this plant which grows in the U.S.A. and Europe. This entry is illustrated by a delightful drawing of a bee hanging from a curved stem, weighed down by four flowers, looking like washing drying in the wind, in particular, four pairs of the sort of voluminous pants an 18th century Dutchman might have worn. The book contains more than 50 black and white line drawings by Amy Jean Porter, one drawing every few pages. They are clear and lively, with a lightness of touch.

I wonder how Ms Gracie picked the 100 or so vignettes. I imagine she could write another and another compendium without any duplication. Where is Humboldt, where is Olmsted? Where are the humming birds, the kniphofias, the gingko bilobas, the honey possum?

But *Florapedia* is not a leaky dictionary; it is a wonderful idiosyncratic, botanical pot pourri. It is an "amuse bouche" that leaves you wanting more, amazed by the marvel of plants. In her introduction Carol Gracie writes that she hopes "the short entries in this book [will] instill an appreciation" of flowers. She achieves her wish totally.

Marion Shawcross

Note: This is the first of a series of short, alphabetically-arranged books by this publisher. Recent additions include *Birdpedia*, *Treepedia*, *Fungipedia* and *Dinopedia*. These are inexpensive hardbacks and would make very suitable small gifts or stocking-fillers.

Tony Payne (Book Review Editor)

Wasps: The Astonishing Diversity of a Misunderstood Insect

Eric R. Eaton
Princeton University Press, 2021. 256 pages, hardback with numerous colour photographs. ISBN 0691211426. £25.00.

Eric R. Eaton is a professional entomologist who has worked for Cincinnati Zoo, Chase Studio, the Smithsonian Institution, universities in Portland State and Massachusetts, and for the West Virginia Division of Natural Resources. Eric is also the author of the *Kaufman Field Guide to Insects of North America* (2007) and co-author of *Insects Did It First* (2018). He is a leading authority on wasps. His writing is empathetic to his study organisms, and the humans with whom he is sharing their wonder. His writing is highly accessible and his passion for his subject is always evident.

This is not a field guide, but a general introduction to wasps. Be warned, the main body text and image captions are tiny; so, make sure you have good light and necessary magnification before you settle down to read. The book is compact, the text is in bite-size chunks and the individual chapters are typically covered in just one or two pages. A well-curated selection of facts and insights into the vast subject of wasps is presented. There is not much of a narrative to drive you through the pages, but there is plenty to be gleaned from thumbing through and dipping into and out of the text. The overall feel of the book is like a more detailed Dorling Kindersley work.

The overarching themes of the book are wasps in the greater contexts of natural ecosystems, human enterprise and culture, and coexistence with people in urban, suburban, and rural environments. The book begins by defining what a wasp is, and sawflies are also included within this definition. The chapters that follow cover wasp evolution, anatomy, metamorphosis, beauty, ecology, diversity, behaviour, mimics, enemies, wasps and people and finally wasp families. Not all the 83 current wasp families are described but there are good summaries of the major family groups. The book introduces wasps from all corners of the world, from miniscule fairy flies to gargantuan tarantula hawk wasps. Throughout the book, there are more detailed profiles of particular wasp species, and spotlights on unique behaviours or relationships to other organisms.

The book is promoted as "the ultimate visual journey into the beautiful and complex world of wasps" and is indeed very visual. It is lavishly and exquisitely illustrated with photographs, artwork and informative infographics. There are over 150 colour images showcasing wasp diversity of form and function.

Whilst some online reviewers have complained about the use of technical language, many of the terms are explained in the text and there is also a helpful glossary at the end of the book. Many tantalising subjects are touched on that you may be compelled to explore further, as the book aims at breadth rather than depth. For those hungry for more detail there is a compact but useful reference list to consult, including both journal publications and websites.

As soon as I have finished this review, I personally am off to investigate "acarinaria" and their occupants - pockets in the exoskeleton of bees and wasps that house mites. Having now learnt that in some instances these parasitic mites act as bodyguards, protecting their hymenopteran hosts from other parasites, I need to know more!

As is indicated by the title, "misunderstood insect", Eric's aim is clearly to help turn public opinion with respect to this much maligned insect group. He says as much to Marc Bekoff, of *Psychology Today*, in an interview he gave following the book's publication in the U.S.A. in March 2021. You can read the full interview at https://www.all-creatures.org/articles2/ar-wasps-misunderstood.pdf. When asked about his audience Eric stated "*Wasps* is aimed squarely at non-experts, including those who may have spheksophobia, the clinical fear of wasps. Knowledge is power, and if the book conveys anything, I hope it communicates how neutral most wasps are in relation to people, if not outright beneficial to our everyday lives". Whilst not principally aimed at those who are already converted with respect to the wonder, diversity, and invaluable wider ecological and societal contributions of wasps, the breadth of subjects covered in the book means that even seasoned insect enthusiasts will learn something.

Wasps are amazing, mostly solitary creatures that thrive in nearly every habitat on Earth, and their influence on our lives is overwhelmingly beneficial. It is good to know that someone is doing their utmost to dispel the biases and hysteria typically associated with these fascinating animals; highlighting the positive relationships they share with humans and the environment to a wider audience. Enjoy!

Jeanne Robinson

Turtles of the World: a Guide to Every Family

Jeffrey E. Lovich & Whit Gibbons
Princeton University press, 2021. 240 pages, hardback with colour photographs and maps. ISBN 9780691223223. (Also available as an ebook).
£25.00

This is a beautifully illustrated book, with one or more stunning colour photographs on nearly every page. Written by two eminent American turtle biologists, it is pretty up to date and highly informative. After a 40-page introduction summarising key aspects of turtle biology (evolution, anatomy, physiology, distribution, behaviour, feeding, reproduction, growth, ecology, cultural significance and conservation), the "meat" of the book (about 180 pages) is the systematic account, describing each turtle family in turn, usually to species level. The basic structure is that each family is given a two-page introduction, including fact boxes on distribution, genera, habitats, size, activities, reproduction and diet. Detailed accounts of each genus follow with more fact boxes and illustrations. The book ends with a set of appendices: glossary of technical terms, a list of conservation organisations, bibliography of books and cited journal articles, and a summary of turtle classification. There is also an index.

An important theme running through the book is the conservation status of turtles around the world, a topic which the authors have addressed in research papers. The bottom line is that over 50% of known turtle species are in the threatened categories, a highly alarming situation. The causes are well known: climate change, habitat loss and over-exploitation head the list. Doing something to reverse the declines is a hard task, often requiring solutions tailored to the situation of particular species.

I mention that the book is pretty up-to-date, following the classification agreed by the Turtle Taxonomy Working Group (TTWG) in 2017. To illustrate the hazards of modern scientific book-writing, this is already superseded. I recently received notice of the 2021 edition of the TTWG checklist, also called *Turtles of the World*, which makes significant changes. Do not confuse the two books: the TTWG checklist is highly technical and aimed at professionals in the field. Newcomers to the field should also appreciate that the term "turtle" also embraces tortoises and terrapins; this book covers all the living shelled reptiles.

So, who is Lovich & Gibbons' book aimed at? This is not particularly clear. There is no preface outlining the authors' intentions, and I found the text a slightly odd mix of technical detail and occasional flippancy. For example, the paragraphs (p. 35) on parental care and sex determination are misleading or unhelpful: what does exceptions to temperature-dependent sex-determination "being rampant" mean? And the claim that "turtles are good parents" falls completely outwith normal definitions of parental care.

I also found some of the design and editorial decisions surprising. The figures are un-numbered and often do not identify the species shown. In-text literature references are quite sparse and frustrating to any reader who wished to follow up the sources of particular details. The lay-out plan means that, where a genus includes only a single species, a fair amount of detail is given (though some accounts are very brief and filled out with pictures), whereas the level of species detail provided for multi-species genera (e.g. *Testudo*, with five species) is very limited. It would appear that the intended readership is mainly American: for example, for species threatened with extinction, listing under the U.S. Endangered Species Act is mentioned, but equivalent legislative protection in other jurisdictions is not covered.

British readers have no terrestrial or freshwater species to see live, unless they visit a zoo with a good reptile collection, though we can count the leatherback sea turtle as a regular visitor to our coastal waters. However, this should not stop us wanting to learn about these fascinating and ancient animals. Despite my minor criticisms, I can thoroughly recommend this beautifully produced and interesting book to start your journey into turtle biology.

Roger Downie

Sharks of the World. A Complete Guide

David A. Ebert, Marc Dando & Sarah Fowler
Princeton University Press, 2nd Edition, 2021. 608 pages, hardback with colour illustrations, colour photos and diagrams. ISBN 9780691210872.
£40.00.

There have been many books on sharks. Most are popular accounts with lavish photos of gnashing teeth and flailing fins. This is not one of those books. This is a shark lover's bible – a complete guide to every shark species known. It was originally published as the *Field Guide to Sharks of the World* in 2005 and subsequently an updated version as *Sharks of the World: A Fully Illustrated Guide* in 2013. Knowledge of sharks is changing so rapidly, with many new species being discovered or recognised, that another revised version was needed. It is now the most comprehensive reference guide available to the world's sharks and a mighty tome at over 600 pages. It covers more than 535 shark species with updated species accounts and the latest taxonomic revisions; it is packed with colour illustrations, photographs and distribution maps of every species. An overview of shark biology, ecology and conservation is provided. The writing style is authoritative, aimed at shark specialists, but still very accessible to the interested layperson. Although the page format is large, the printed font is rather small. This enables a lot of information to be packed in, but you may need your reading glasses!

The introduction is quite short and outlines how best to use this guide; it also defines what a shark is and how they align with the other orders of cartilaginous fish, including many extinct orders. The nomenclature for shark topography (i.e. morphology) is illustrated in detail for features of the body, fins, head and teeth together with a summary of how shark species are named is given. A short section on the evolution of fishes and sharks follows. Since shark evolutionary history goes way back to the Devonian "Age of Fishes" (well before the dinosaurs appeared), incorporates a "Golden Age of Sharks" in the Carboniferous, and incorporates several mass extinction events to the present day, there is a lot to cover in a mere four pages. A beautiful timeline illustration of shark evolution is provided set against the evolution of other major faunal groups. This would make an amazing wall chart. However, the species diagrams here are only thumbnail size, which is a little disappointing – especially for the figured *Megalodon*, the largest shark ever known to exist. One is left wanting to know more about shark evolution, including some of the more bizarre shark-like fish from the past such as the whorl-toothed *Helicoprion* and the weird *Akmonistion*, with its strange spiny dorsal appendage - the latter better known in Glasgow as the "Bearsden Shark".

A lengthy section of 40 pages follows on shark biology and here the guide really excels with beautiful coloured cutaway diagrams illustrating the body structure (inside and out), skeleton, movement, respiration and circulation, skin and scales, senses, feeding and digestion. Shark life histories, behaviour, genetics, and current research priorities are also covered. This section is a book in itself and a real "tour de force". Even if you are already familiar with the anatomy and physiology of sharks it is still a joy to browse. Never have bones, blood, brains and guts seemed so fascinating. Here you can delve into many of the evolutionary inventions of elasmobranchs: the light-weight cartilaginous skeleton; the development of jaws and diversification of teeth; the conveyor belt tooth replacement system; ram ventilation of the gills; thunniform swimming modes; laminar flow dermal denticles; bioluminescence; osmoregulation using metabolic wastes such as urea; heat-exchanging blood vessels and a primitive form of endothermy; olfactory, pressure and electro-sensing; plankton feeding megabeasts; intestinal spiral valves; internal fertilisation, uterine feeding (and cannibalism) and viviparity.

In recent years electronic tagging of sharks has increased knowledge of the migration patterns of many species for feeding or breeding purposes. The great white shark is now known to migrate from California to Hawaii but regularly stops off halfway between to feed at a deep-water fish and squid "café". Great white sharks have also been tracked crossing from South Africa to Western Australia. Disappointingly, the authors have dropped the "great" moniker from its common name but, at the risk of being accused of populism, I prefer to make the white shark great again! The adoption of new genetic analysis techniques, using small fin clips or environmental DNA in water samples, is casting new light on shark breeding behaviour (e.g. by checking paternities of young), as well as revealing the occurrence of cryptic species. Surveys using eDNA may be far more effective than traditional labour-intensive visual surveys.

The section on "Sharks and People" is a cornucopia of detailed information covering shark legends (which feature notably in Mediterranean and Polynesian culture), shark fisheries, shark tourism and shark conservation. It highlights many of the problems sharks face worldwide from overfishing, fisheries bycatch, finning etc. Sharks have been targeted commercially for their meat, fins, liver oil, cartilage and skin and it is a depressingly familiar story of over-exploitation. Basking sharks were still being hunted for their oil in the west of Scotland just a few decades ago. The negative portrayal of sharks in the 1975 horror film *Jaws* did not help their image and shark conservation only began to be considered in the 1980s. Many species are now protected, and finning is banned in many countries, but fisheries management and regulation remains a challenge. The growth of shark tourism has helped encourage conservation work. However, the conflict between sharks and recreational swimmers and surfers remains, although actual shark attacks are relatively rare.

The largest part of this book, a whopping 490 pages, consists of a key to the four orders and 36 families of extant sharks and individual accounts for all 535 known species. Each family group of sharks is illustrated initially with beautiful colour plates depicting the various species, as if in life, all to the same scale and each orientated at similar angle to allow easy comparison. As in any modern field identification guide, each plate is accompanied by an opposing page of text bullet points summarising the distribution and key identification features. A common name is given for every species, accompanied by the proper scientific name, but only the latter is tagged on the plates which can be a little annoying for the non-specialist. Along with the family portraits each family is discussed with regards to its identification, biology, and conservation status. A synopsis of information on each individual species is also provided in a standardised format with one or two species per page. This includes line drawings of the body viewed laterally (or dorsally for compressed species), drawings of the head and mouth area from below and (for many species) notes and diagrams of the teeth. The drawings are augmented with notes on species identification, measurements, distribution, habitat, behaviour, biology, and status. World distribution maps are provided for each species, and for fisheries scientists the three-letter Food & Agriculture Organisation (FAO) code is given.

Among the species accounts you can get down to the details of some of the more peculiar sharks: strange frilled sharks with protruding gills and tricuspid teeth; hammerhead sharks with their weird head structure; lanternsharks with various bioluminescent species and the world's smallest sharks under 20 cm at maturity; sleeper sharks such as the Greenland shark which may live for over 100 years; sawsharks (not to be confused with similar looking sawfish, allied to the rays); huge plankton feeding whale sharks, basking sharks, and megamouth sharks; cookiecutter sharks which bite chunks of flesh from whales, seals, or other large fish; the zebra shark whose young mimic the banded colouration of sea snakes; and the amazingly camouflaged wobbegongs, to name but a few. There are numerous more "ordinary" sharks and some of their common names tell a story in themselves. As well as great white sharks, tiger sharks, crocodile sharks, and requiem sharks, which all sound ominous, there are angel sharks, shy sharks, nervous sharks, and pyjama sharks, which sound quite innocuous. The shy shark habitually covers its eye with it tail when captured. The phallic catshark is possibly proud of its name but the flaccid catshark may not be quite so pleased! One should be careful not to let the bignose shark hear you say its name… as it is also a very big shark up to 3 m in length with big teeth too!

While the comprehensive scope of this book will appeal mostly to fishery scientists and conservationists, it indispensable to any shark enthusiast wishing to learn more about sharks and to gain a worldwide perspective on this fascinating and ancient group of fish.

Myles O'Reilly

The Glasgow Naturalist (2022) Volume 27, Part 4, 94-99

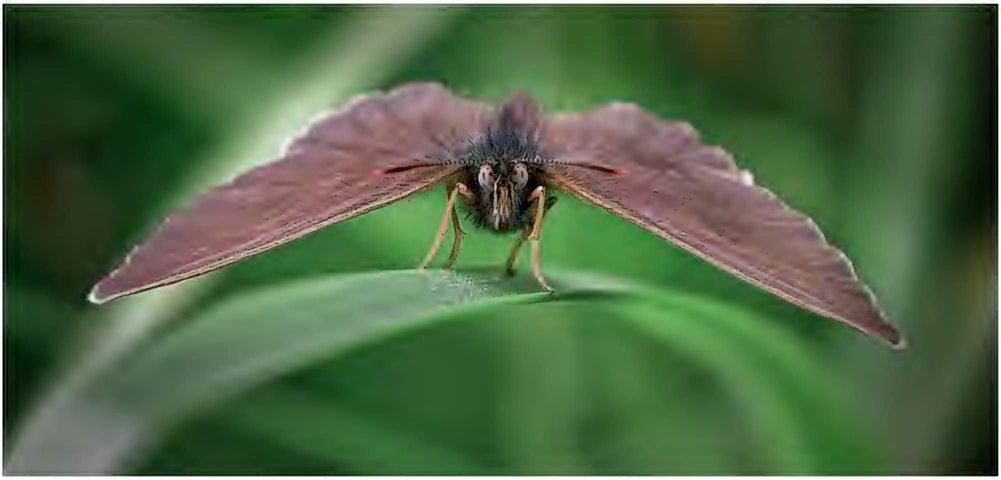
PhotoSCENE 2021-22

PhotoSCENE Natural History Photographic Competition

The annual PhotoSCENE competition is sponsored by Glasgow Natural History Society and the University of Glasgow Institute of Biodiversity, Animal Health and Comparative Medicine. It aims to promote interest in natural history and the work of SCENE (Scottish Centre for Ecology and the Natural Environment, the University's field station at Rowardennan, Loch Lomond), promote linkage between the Institute and the Society, and provide pictures for publicity. All entrants are thanked for making the effort to enter the competition. Prizes totalling £800 per year have been awarded at the Society's photographic nights. Since the first competition in 2011, and together with talks from members, the competition has provided us with an interesting photographic evening each February. This year there were 72 entries from 18 people.

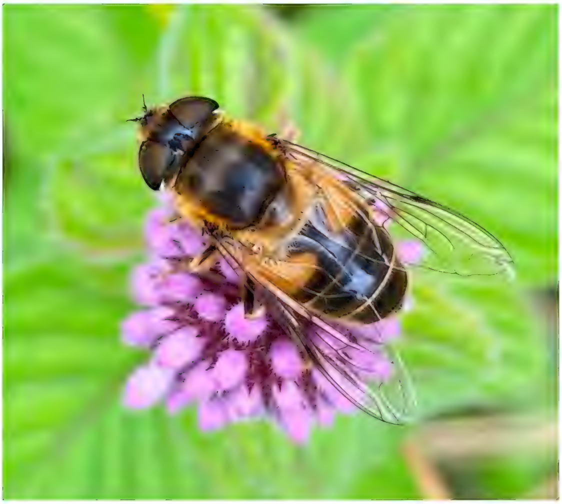
D.C. Palmar

Overall winner:

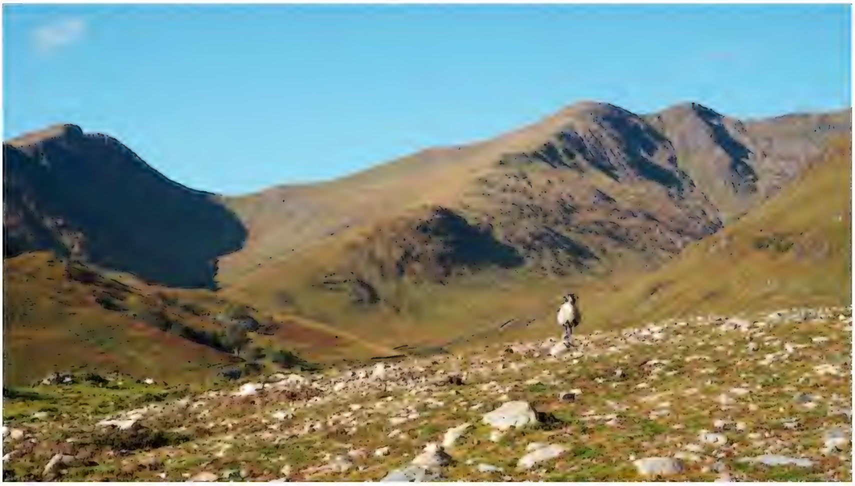


Andy Wilson – Ringlet butterfly (*Aphantopus hyperantus*), Holmhills Wood, South Lanarkshire, Scotland, 9th July 2021.

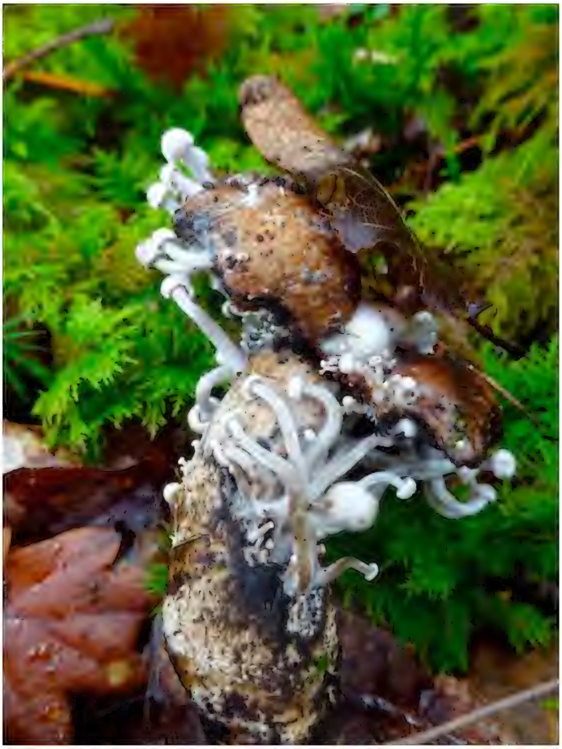
Other Prize Winners:
These include the photographs by Eleni Christoforou and Richard Sutcliffe that feature on the front and back covers respectively. Information on these photographs is provided on the inside front cover. The other prize winners are shown below and on the following pages.



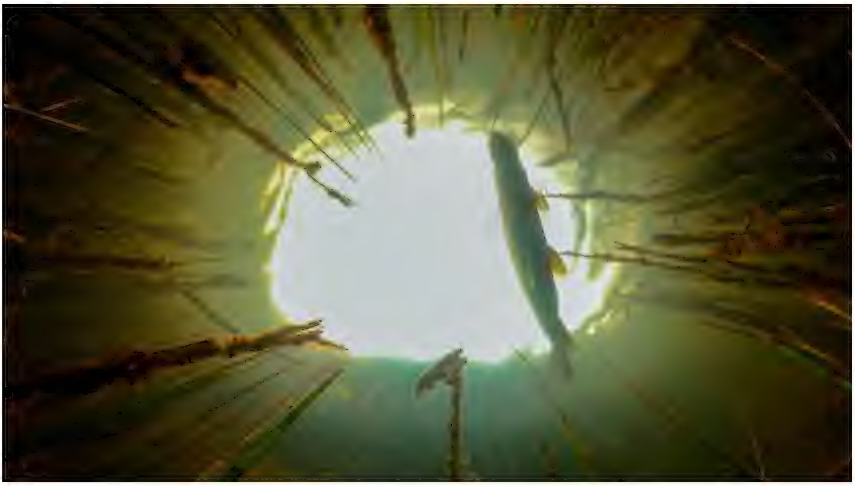
Scott Shanks - Female tapered drone fly (*Eristalis pertinax*) on water mint (*Mentha aquatica*), Blairlinnans, West Dunbartonshire, Scotland, 23rd November 2021.



Chanakarn Wongsaengchan – Meet the local! Near Beinn a'Chochuill, north of Loch Awe, Argyll, Scotland, 2nd October 2020.



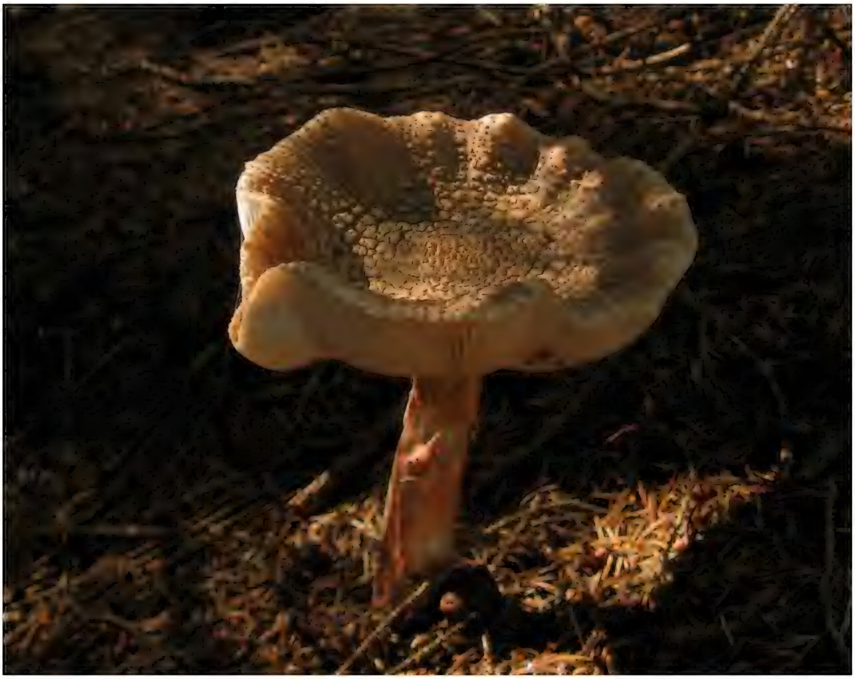
Jaime Villacampa – Silky piggyback (*Asterophora parasitica*) growing on a decaying fruiting body of the blackening brittlegill (*Russula nigricans*), Sallochy, Loch Lomond, Scotland, September 2021.



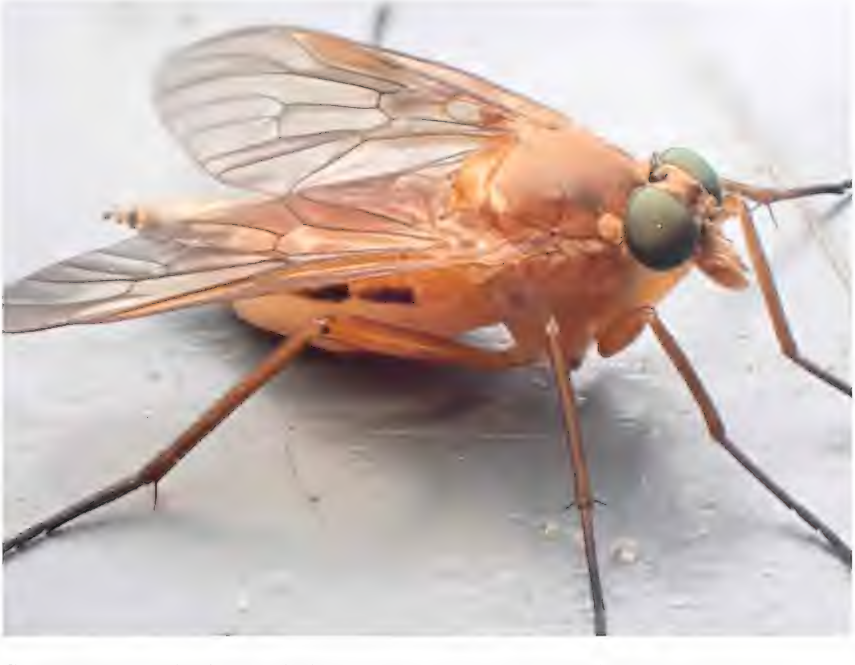
Jonathan Archer – Pike (*Esox lucius*), in Dubh Loch, Scottish Centre for Ecology and the Natural Environment (SCENE), Loch Lomond, Scotland, 29th July 2021. Taken with a GOPro 360max camera in an underwater housing.

Laura Allen – Golden-ringed dragonfly (*Cordulegaster boltonii*), near Inversnaid, Loch Lomond, Scotland, 10th July 2021.

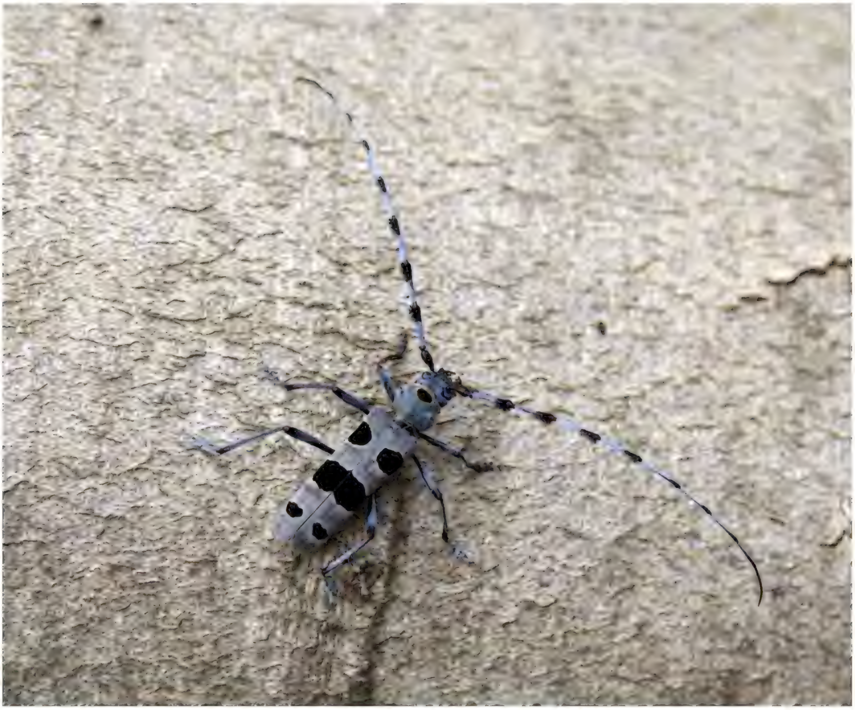
Chris McInerny – Vapourer moth caterpillar (*Orgyia antiqua*), Stirlingshire, Scotland, 24th August 2021.



Sarah Longrigg – Blusher mushroom (*Amanita rubescens*), Drymen, Stirlingshire, Scotland, 26th August 2021.



Gordon Brady – Snipe fly (Rhagionidae), Gartcosh, Glasgow, Scotland, 29th July 2021.



Jonas Gaigr – Alpine longhorn beetle (*Rosalia alpina*), Bile Karpaty Protected Landscape Area, Czech Republic, 20th July 2021.

The Glasgow Naturalist (2022) Volume 27, Part 4, 100-101

PROCEEDINGS 2020

From March 2020 the coronavirus (COVID-19) pandemic disrupted GNHS activities. No talks were held in April, May, or June and from September all were held online via Zoom. A two-day conference on the life and scientific legacy of Edward Stuart Russell and the entire excursion programme were cancelled.

For each meeting the lecturer's name and the title of the lecture are given. Location of meetings is also given, where relevant. Both in-person and virtual meetings were reasonably well attended.

January 14th
Exhibition Visit: "Exploration – from deep time to deep space" led by Jeanne Robinson. Hunterian Museum.

January 29th
Blodwen Lloyd Binns Lecture: "A natural history of immune defences in this wormy world" from Andrea Graham. Graham Kerr Building.

February 11th
Photographic Night. Members' slides or digital slide shows, plus results of the PhotoSCENE competition. Boyd Orr Building.

March 5th
Expeditions Report Back, jointly with the University of Glasgow Expeditions Society. (Most expeditions are supported by the BLB Bequest.) Graham Kerr Building.

March 10th
Annual General Meeting, followed by Lecture: "From science to policy – protecting the marine environment" from Lyndsey Dodds. Boyd Orr Building.

April, May and June
Due to COVID-19 restrictions on socialising, all scheduled events - meetings, conference and Summer Social - were cancelled.

September 15th
Lecture: "Honey-buzzards in Central Scotland" from Chris McInerny. Online via Zoom.

October 13th
Lecture: "Glasgow's West End wildlife" from David Palmar. Online via Zoom.

November 3rd
Lecture: "Plants and climate change" from Isla Myers-Smith. Online via Zoom.

December 8th
Lecture: "Follow the Leader: Exploring the Social behaviour of fishes" from Shaun Killen. Online via Zoom

Excursions
No excursions were held during 2020.

Officers and Council elected at the 2020 AGM

President
Chris McInerny

Vice Presidents
Barbara Mable
Roger Downie

General Secretary
Mary Child

Assistant Secretary
Lyn Dunachie

Treasurer
Susan Futter

Winter Syllabus
Roger Downie

Excursions
Alison Moss

Membership Secretary
Richard Weddle

Librarian
Myles O'Reilly

***The Glasgow Naturalist* Editor**
Iain Wilkie

***The Glasgow Naturalist* Assistant Editors**
Chris McInerny
Ruth Maclachlan

Newsletter Editor
David Palmar

Section Convenors
Richard Weddle: Bio-recording
Alison Moss: Botany
Ann Ainsworth: Geology
David Palmar: Photography
Myles O'Reilly: Zoology

Councillors
Bob Gray
Janet Palmar

Kirsty Kennedy-Wylie
Laura Allen
Tony Payne

BLB Executive
Chair: Barbara Mable
Secretary: Mary Child
Treasurer: Susan Futter
Scientific Advisor: Tony Payne
Technical Advisor: Richard Weddle
Financial Advisor: Bob Gray

The Glasgow Naturalist

Information for Contributors

1. *The Glasgow Naturalist* publishes full papers, short notes and book reviews. All articles are peer reviewed by a minimum of two reviewers. The subject matter of papers and short notes should concern the natural history of Scotland in all its aspects, including historical treatments of natural historians. Details of the journal can be found at: www.gnhs.org.uk/publications.html

2. Full papers should not normally exceed 20 printed pages. They should be headed by the title and author, postal and email addresses. Any references cited should be listed in alphabetical order under the heading References. All papers must start with a short abstract of up to 200 words, which should summarise the work. The text should normally be divided into sections with sub-headings such as Introduction, Methods, Results, Discussion, Acknowledgements and References.

3. Short notes should not normally exceed two printed pages. They should be headed by the title and author's name, postal and email address. Any references cited should be listed in alphabetical order under the heading References. There should be no other sub-headings. Any acknowledgements should be given as a sentence before the references. Short notes may cover, for example, new locations for a species, rediscoveries of old records, ringed birds recovered, occurrences known to be rare or unusual, interesting localities not usually visited by naturalists, and preliminary observations designed to stimulate more general interest.

4. References should be given in full according to the following style:

Pennie, I.D. (1951). Distribution of capercaillie in Scotland. *Scottish Naturalist* 63, 4-17.

O'Reilly, M., Nowacki, S. & Gerrie, E. (2018). New records of the white-banded grapple-worm. *The Glasgow Naturalist* 26(4), 96-97.

Wheeler, A. (1975). *Fishes of the World*. Ferndale Editions, London.

Smith, C.W., Aptroot, A., Coppins, B.J., Fletcher, A., Gilbert, O.L., James, P.W. & Wolseley, P.A. (2009). *The Lichens of Great Britain and Ireland*. (2nd edition). The British Lichen Society, London.

Grist, N.R. & Bell, E.J. (1996). Enteroviruses. In: Weatherall, D.J. (Editor). *Oxford Textbook of Medicine*, pp. 381-390. Oxford University Press, Oxford.

References with more than six authors: name the first six authors, then add "*et al.*"

5. References should be cited in the text as follows:

Single author: Pennie (1915)… (Pennie, 1915). Two authors: Grist & Bell (1996)… (Grist & Bell, 1996). More than two authors: Smith *et al.* (2009)… (Smith *et al.*, 2009). Multiple citations: (Pennie, 1915; Grist & Bell, 1996). Same author(s), publications in different years: (MacGillivray, 1840, 1855).

6. An organism's genus and species names should be given in italics when first mentioned. Thereafter only the common name is required. Please use lower case initial letters for all common names, e.g. wood avens, blackbird, unless the common name includes a normally capitalised proper name, e.g. Kemp's ridley turtle. The nomenclature of vascular plants should follow Stace, C.A. (2019). *The New Flora of the British Isles*. (4th edition). C&M Floristics, Stowmarket. Normal rules of zoological nomenclature apply. When stating distribution, it may be appropriate to give information by vice-county.

7. All papers, including electronic versions, must be prepared on A4, double spaced throughout, with margins of 25 mm, with 12 point Times New Roman font. Tables and the legends to figures should be typed on separate pages at the end of the manuscript.

8. Tables are numbered in arabic numerals, e.g. Table 1. These should be double-spaced on separate pages with a title and short explanatory paragraph underneath.

9. Line drawings and photographs are numbered in sequence in arabic numerals, e.g. Fig. 1. If an illustration has more than one part, each should be identified as, e.g. 9A, B etc. They should be supplied as high resolution digital images either in separate files or on separate pages at the end of the manuscript: they should not be embedded in the text. A metric scale must be inserted in photomicrographs etc. Legends for illustrations should be typed on a separate page.

10. Authors should assure the Editor explicitly that all illustrations, including maps, do not infringe copyright law.

11. Articles should be submitted to the Editor: Dr Iain Wilkie by email Editor@gnhs.org.uk as a single word-processed document. Photographs and illustrations should be high resolution with a minimum of 300 dpi in tif or jpeg format.

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